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BEET SUGAR WASTE TREATMENT BY BROAD FIELD APPLICATION-GREAT WESTERN SUGAR COMPANY, BAYARD, NEBRASKA.

Public Health Service
Kansas City, Missouri

April 1954

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Great Western Sugar Company, Bayard, Nebraska

October – December, 1953

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Public Health Service

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BEET SUGAR WASTE TREATMENT BY BROAD FIELD APPLICATION

Great Western Sugar Company, Bayard, Nebraska

October - December, 1953

An evaluation of the method employed by the Great Western Sugar Company at its Bayard, Nebraska, plant to treat straight house beet sugar wastes by application of a natural grassland field

Details of illustrations in this document may be better studied on microfiche

April 1954

U. S. Department of Health, Education and Welfare
Public Health Service
Division of Water Pollution Control
Missouri Drainage Basin Office
Kansas City, Missouri

I

BEET SUGAR WASTE TREATMENT BY BROAD FIELD APPLICATION

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PREFACE

The early history of beet sugar is clouded in the vastness of antiquity. It is believed that the Chinese made a crude sugar from beet juice since very early times.[1] European discovery is attributed to Scientist Margraff in 1747, although processing was not successful commercially until a student of Margraff, 52 years later, submitted a practical method for evaluation by the Institute of France. The result was the opening of a small factory at Breslau in 1801, the forerunner of the gigantic beet sugar industry.

In 1810, Napoleon I encouraged home cultivation of beets and the production of beet sugar; a price of 1,000,000 francs was offered for the best method of manufacture. The product improved and by 1840, 50,000 tons of beet sugar annually were being produced. By 1900, western civilization was consuming more beet than cane sugar although this trend was reversed by serious setbacks to the beet fields of France and Russia during World War I.

The cultivation of sugar beets was introduced into the United States in 1880. By 1948, 85 plants operating in 16 states produced 1,369,000 tons of beet sugar from 9,422,000 tons of beets, which represented 12.3 percent of the world total.

Associated with beet sugar manufacturing is the necessity for a copious supply of water and the related problem of waste disposal. For each ton of beets processed, 2,500 to 3,500 gallons of water are used, and plant capacity varies from 1,000 to 5,900 tons of beets per day. It has been estimated that during the season of operation the industry in the United States discharges liquid wastes having a population equivalent potential of 17,000,000 based on biochemical oxygen demand.[2]

It is to the credit of the beet sugar industry that cognizance is made of stream pollution problems caused by large discharges of untreated wastes and that efforts are being made to correct this condition. The Great Western Sugar Company has studied various waste disposal systems, has utilized several methods for treatment of its wastes, and is now evaluating application of factory wastes to a grassland field prior to their ultimate discharge to a watercourse. It is hoped that this study of the Great Western Sugar Company's waste disposal field at Bayard, Nebraska, will assist the industry in its efforts to abate and prevent stream pollution.

INTRODUCTION

On the north bank of the North Platte River in the shadow of famous Chimney Rock, which overlooks the broad valley where once resounded the hoofbeats and wagoncreaks of the pioneers trekking the Oregon Trail and echoed the war cry of the Sioux and Pawnee, lies the town of Bayard, Nebraska. It was at the sugar beet plant in this community that the Great Western Sugar Company decided to experiment with plant scale utilization of a natural grassland field for treatment of the water-carried wastes. Because of promising results of the investigation, an invitation was extended by Mr. Avery A. Clark, Assistant to the President, Great Western Sugar Company, to public health agencies to inspect the facilities. In the latter part of November, 1952, representatives of the State Health Departments of Colorado, Nebraska, North Dakota, and Wyoming, the U. S. Public Health Service, and the Great Western Sugar Company met at Bayard for this purpose. Unfortunately, a blizzard swept the area that day and hindered greatly the inspection trip. Yet the facility appeared to be achieving favorable results and to warrant additional study. Subsequent meetings were held with representatives of the health agencies and of the Company and a joint study program was formulated, to be initiated during the 1953 operation of the plant.

A work plan was drafted by the Missouri Drainage Basin Office and reviewed by the Nebraska Department of Health, the Great Western Sugar Company, and the Division of Water Pollution Control and the Robert A. Taft Sanitary Engineering Center of the Public Health Service. After incorporation of appropriate suggestions, the plan was approved by the reviewing agencies. Minor modifications were subsequently made as necessary to crystallize this joint activity, although final arrangements followed essentially the preliminary plan.

Under direction of the Missouri Drainage Basin Office, U. S. Public Health Service, the efforts of the cooperating agencies -- the Great Western Sugar Company, the State Health Departments of Nebraska and Wyoming, and the U. S. Public Health Service -- were coordinated, and a six-man survey team was assigned to the field for one month starting October 19, 1953, to secure laboratory and other basic data. The team consisted of a sanitary engineer, a chemist, a bacteriologist, and three sample collectors. The bacteriologist and one sample collector were furnished by the Nebraska Department of Health; the others were U. S. Public Health Service personnel. In addition, the Assistant Basin Engineer, Missouri Drainage Basin Office, assisted in establishing the field study, and the Basin Biologist conducted the limnological investigations.

Laboratory space and utilities were provided by Great Western at the Bayard factory laboratory, and laboratory and field equipment were supplied by the States of Nebraska and Wyoming, and the Public Health Service. Solids determinations, supplemental analyses, and certain parallel tests were made by the Great Western Sugar Company. Chemical analyses of specific samples were conducted at Lincoln by the Division of Laboratories, Nebraska Department of Health. U. S. Weather Bureau temperature station, rainfall gage and evaporation measuring equipment were set up in the field and U. S. Geological Survey flow recorders were installed at the field inlet and outlet. Climatological data were recorded and the equipment maintained under direction of the Chief Chemist of Great Western's Bayard plant. The flow

recorders were maintained by the Nebraska Department of Roads and Irrigation.

The Public Health Service, through its Missouri Drainage Basin Office, was delegated the responsibility of preparing a draft report for review and comment by the cooperating agencies, following which it would release a final report. The agencies reviewing this report in draft form include: the Nebraska Department of Health, the Wyoming Department of Public Health, the Great Western Sugar Company, and the Division of Water Pollution Control and the Robert A. Taft Sanitary Engineering Center of the U. S. Public Health Service.

Personnel from all the above cooperating agencies gave splendid cooperation to the project. The spontaneous response of the Bayard plant superintendent, B. F. Hostetler, and his Chief Mechanic, W. F. Hartney, to many requests for assistance by the field men was specially gratifying. Special recognition must be given to the fine, cooperative spirit of the survey team, working under the direction of Sanitary Engineer W. H. Davis, Jr.

ACKNOWLEDGMENT

This study was made possible by the excellent cooperation of the agencies sharing in the joint venture. Opportunity is taken to gratefully acknowledge the help provided by all.

The following cooperated with or participated in this study:

Great Western Sugar Company

Avery A. Clark, Assistant to the President - Denver
E. H. Hungerford, General Chemist - Denver
John Hedde, Chief Chemist, Process Development Laboratory - Loveland
L. H. Henderson, Manager - Bayard plant
B. F. Hostetler, Superintendent - Bayard plant
W. F. Hartney, Master Mechanic - Bayard plant
J. R. Corsberg, Chief Chemist - Bayard plant

Nebraska Department of Health

Division of Sanitation

T. A. Filipi, Director
Philip Slagel, Sanitary Engineer - Survey Team
William F. Rapp, Scientist - Survey Team

Division of Laboratories

L. O. Vose, Director
John Cooper, Bacteriologist - Survey Team

Nebraska Department of Roads and Irrigation

E. S. Kimmel, Principal Hydrographer
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Wyoming Department of Public Health

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U. S. Public Health Service

Missouri Drainage Basin Office

Glen J. Hopkins, Officer in Charge
Ralph Porges, Assistant Basin Engineer
Joe K. Neal, Basin Biologist

Survey Team

W. H. Davis, Jr., Project Engineer
Carl N. Shadix, Project Chemist
Paul Jones, Engineering Aide
Melvin Curry, Aide

SUMMARY

A joint study was established to evaluate treatment of the Great Western Sugar Company's Bayard plant wastes by broad application to a natural grassland field. Agencies cooperating in this venture were the Great Western Sugar Company, the Health Departments of the States of Nebraska and Wyoming, and the U. S. Public Health Service. Assistance was also rendered by the U. S. Weather Bureau, the U. S. Geological Survey, and the Nebraska Department of Roads and Irrigation.

A six-man survey team, under the direction and coordination of the Missouri Drainage Basin Office, Public Health Service, was assigned to the field for one month starting October 19, 1953, to secure laboratory and base data. Personnel and laboratory facilities were jointly provided by the several cooperating agencies.

The Great Western Sugar Company operates at Bayard a typical straight house plant. Wastes originate primarily from flume and beet wash water, pulp screen water, pulp press water, and lime cake wastes. The 1953 campaign averaged a daily slice of 1,890 tons of beets; finished products are sugar, molasses and stock feed.

A clear water drain ditch of perennial flow, passing through the plant property, supplies the processing water and is the ultimate recipient of treated and untreated wastes. Approximately 8 c.f.s. are diverted daily from the ditch for factory use.

The liquid wastes exceeded 2,400 gallons per ton of beets processed and had a population equivalent based on B.O.D. of 52.4 per ton. The total 5-day 20°C. B.O.D. approximated 16,500 pounds. Sixty-eight percent of the B.O.D. produced was applied to a natural grassland field for treatment while the remainder reached the ditch untreated.

The treatment field consists of 160 acres roughly rectangular in shape, 3,500 feet long and 1,750 feet wide. Application of wastes is by a distribution flume; outlets to the field are 4" pipes spaced at 25-foot intervals. The waste flows over a portion of the grassy surface and is collected at the lower end in a canal and discharged to the drain ditch. It is estimated that approximately 60 percent of the field was in use.

Of the 4.3 c.f.s. with an average of 483 ppm. B.O.D. applied to the field during the sampling period, 3.5 c.f.s. with an average B.O.D. of 158 ppm. was returned to the drain ditch as effluent from the field after an average of 14.5 hours detention in the treatment plot. The B.O.D. removal in ppm. was 67 percent while over 73 percent of the pounds B.O.D. applied remained on the field. Suspended solids removal exceeded 99 percent.

The grassland plot acted primarily as a settling area with supplemental biological action. The settleable material dropped out within the upper quarter of the field with a corresponding B.O.D. reduction of 60 percent. In the lower portion of the field, B.O.D. was reduced by another 7 percent and dissolved solids by about 10 percent. Even though dissolved oxgen was not detected in appreciable amounts in the treatment field or treated effluent, odors were at a relatively low level during most of the study period.

Bacteriological reduction through the field was 89 percent for MPN of coliforms and 75 percent for total 37°C. count. Algal and protozoan growths were present in large numbers especially in the quiescent reaches of the field.

Effluent from the treatment field, waste discharged directly to the drain ditch, and inadvertent spillage or overflow of untreated waste and partially settled liquor from the treatment plot increased the average B.O.D. in the drain ditch from 2.37 ppm. to 52.4 ppm. while the average D.O. dropped from 9.89 ppm. to 5.74 ppm. The minimum D.O. recorded in the ditch was 4.19 ppm., which is below the 5.0 ppm. level established as desirable for nontrout waters in the Missouri Basin. Dissolved oxygen declined in the North Platte River below the entrance of the drain ditch.

The application of wastes from the Bayard sugar beet factory to the natural grassland treatment plot appears to be an effective method for reducing pollution. This method, applied to all wastes emanating from the Bayard factory, would provide adequate treatment to prevent the occurrence of adverse conditions from these wastes in the receiving stream.

The treatment of beet sugar wastes by broad field application appears satisfactory for installation at other factories in the North Platte valley, along the Yellowstone River, and elsewhere where the degree of treatment provided by this method will be compatible with the dilution afforded by the receiving stream. It should find general application, particularly since the method has flexibility. Where a lesser degree of treatment is required, a much smaller plot to provide settling only might suffice. Leveling and terracing of the field will permit additional detention time with a higher degree of purification. Removal of lime cake, either dry or as a slurry, for separate treatment, disposal or for reuse, would provide additional flexibility. The economics of each individual instance as decided by engineering evaluation will probably dictate the ultimate disposal method.

The Great Western Sugar Company should continue evaluation of its waste disposal program at Bayard and the use of broad field application for treatment of factory waste. Study may well be expanded to include waste and water use reduction, and possible waste salvage and reclamation.

Recommendations are made towards improving operation of the treatment field such as improving distribution methods, leveling and terracing to increase detention time, and providing accessibility to facilitate maintenance and operation.

RECOMMENDATIONS

1. All wastes emanating from the Bayard factory be applied to the treatment field.

2. The waste discharge be more closely controlled to prevent inadvertent spillage or overflow to the drain ditch.

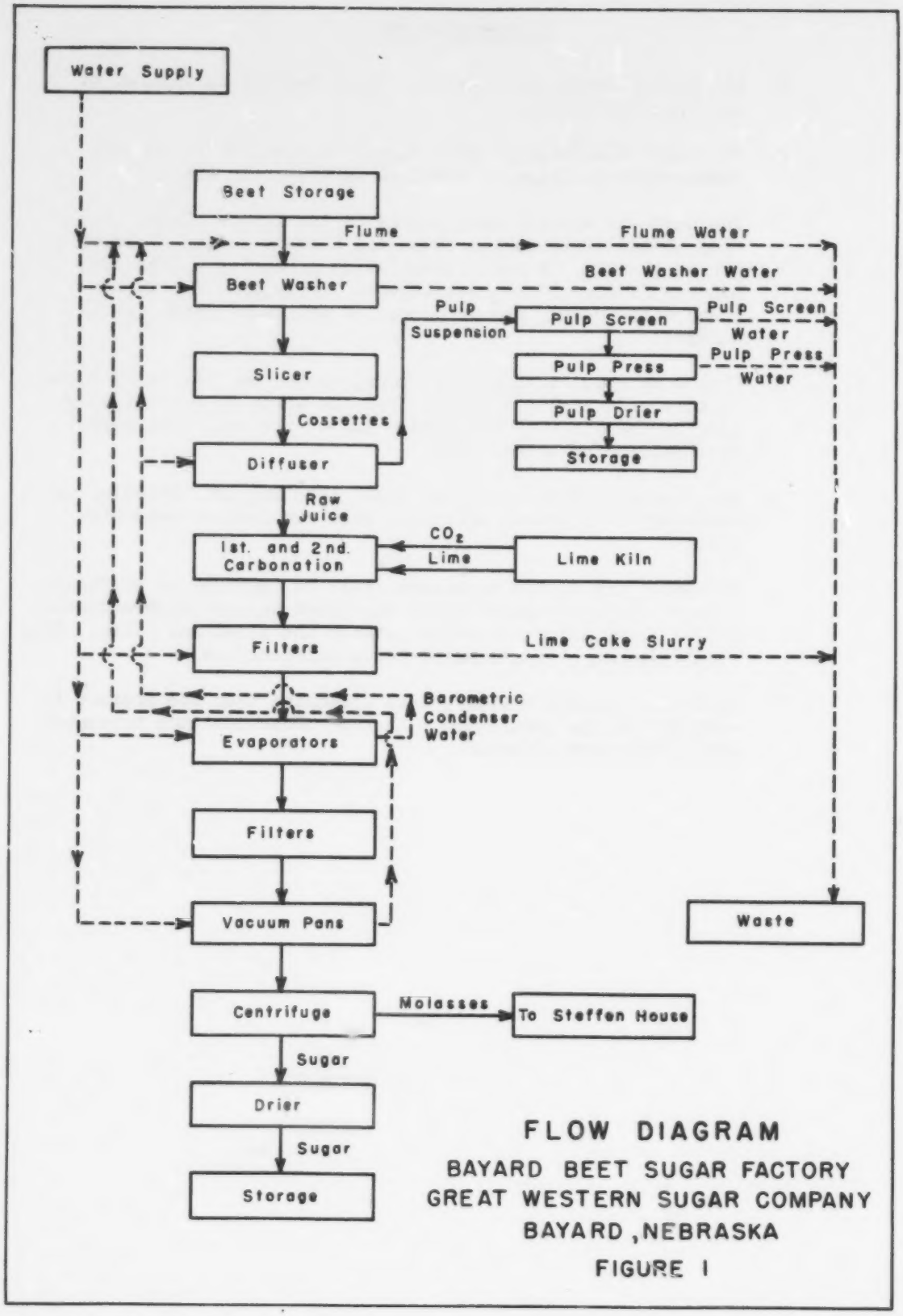
3. The waste be applied more evenly to the field. Reconstruction of the distribution flume and headers to the field will assist greatly. A pump installation producing a more continuous flow would be advantageous. Providing for these items will greatly reduce operation and maintenance difficulties.

4. Coarse material such as beet tops, roots, and pieces of beets be more effectively screened from the waste to prevent clogging at the distribution header and at the same time permit reclamation for animal feed.

5. The treatment field be given minor leveling and terracing as necessary to increase effective area and improve detention time.

6. Accessibility to the treatment field be improved by construction of roadways, possibly on the dikes supporting the distribution flume and on the dike between the field and ditch. This should reduce over-all maintenance difficulties.

7. Another cooperative study, less intensive than the present investigation, be instituted when the recommendations presented above have been effected.



FLOW DIAGRAM

BAYARD BEET SUGAR FACTORY
GREAT WESTERN SUGAR COMPANY
BAYARD, NEBRASKA

FIGURE I

PLANT OPERATION

Organization

The Great Western Sugar Company, with 17 factories operating in the western states, has its main offices at Denver, Colorado; a district office is at Scottsbluff, Nebraska. The latter office supervises operations for the several plants located in Nebraska, at Lovell, Wyoming, and at Billings, Montana. The Bayard plant was built in 1917. Figure 2 includes a panoramic picture of this factory taken during the present study.

Raw Materials and Products

Sugar beets are secured from local farms of the North Platte valley. Other raw materials include lime rock, sulphur, soda ash, coke and coal.

Products of the Bayard plant include sugar, molasses, and dried pulp.

Capacity

The plant has a rated capacity of 1,850 tons of beets per day. During the 1952-53 campaign, the average daily cut was 1,769 tons with a maximum of 1,983 tons. Similar data for the 1953-54 run showed an average of 1,890 tons and a maximum day of 2,025 tons.

Employees

A total of 205 men work in the factory on three shifts. In addition, there are 8 or 9 office and 12 laboratory employees.

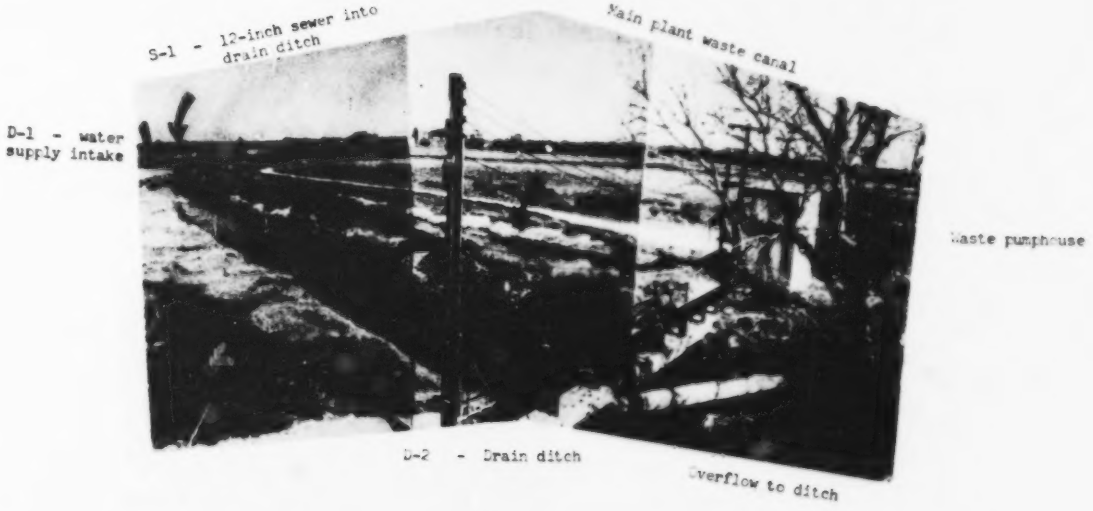
Process

Beet sugar plant operation is continuous, barring accicental stoppage, from the start of the fall campaign until all beets are processed. The 1952 operation commenced about October 11 and lasted for 89 days; the 1953 start was October 8 and continued for 73½ days.

A flow diagram showing plant processes, water used, and wastes produced is sketched as figure 1. The beets are conveyed to the plant from storage by water flowing in flumes. Leaves, floating debris, sand, and beet rootlets are removed by screening as the beets are washed in the flume and washers. The washed beets are sliced into long, narrow, V-shaped ribbons called "cossettes". Conveyor belts transport the "cossettes" to diffusers for the extraction of sugar by counterflow with hot water. The raw juice is subjected to chemical treatment and filtration following which it is concentrated in multiple-effect evaporators and finally crystallized in vacuum pans. The residual molasses is shipped to a Steffen House plant for additional sugar recovery or for by-product recovery. The spent "cossettes" are drained, then further dewatered by pressing, and finally dried and bagged as a high grade stock food.

Figure 2

Great Western Sugar Company - Bayard, Nebraska


S-1 - 12-inch sewer into drain ditch
Main plant waste canal
D-1 - water supply intake
Waste pumphouse
D-2 - Drain ditch
Overflow to ditch

Drain ditch and main plant waste canal above ditch flowing to lift station for pumping to treatment field distribution header.

Drain ditch

Evaporation pan

F-1 - Flume (rotary screen in foreground)

Grassland Treatment Field.

Water Supply

Process water is diverted from an irrigation drain ditch variously known as the Stuckenholtz Irrigation Ditch, the Bayard Sugar Factory Drain, or the Shortline Ditch (figure 3 and 4). It is reported that approximately 43,200,000 pounds or about 5.2 M.G.D. are diverted for average usage. An auxiliary supply of 6 wells is seldom used. A drilled well supplies potable water.

Wastes

The Bayard plant operates as a non-Steffen (straight) house sugar factory. Wastes from this type of process have been frequently evaluated and are known to contain considerable organic matter and some mineral constituents.

Flume and Wash Water

Flume and wash water which amounts to about 75 percent of the total water used at the plant convey beets from storage piles and sheds to the factory. Some of the leaves, beet particles, and beet rootlets are screened out and used for stock feed. Principal pollutants from the operation are the aforementioned items and dirt washed from the beets. An average of 30 pounds of dirt may be removed per ton of beets; wet weather conditions will increase this amount by over 50 percent. Additional polluting matter may arise from organic material and sugar dissolved from spoiled or frozen beets.

The flume and wash water make-up includes fresh water and that from the barometric condensers. Sufficient heat is carried by the condenser water to maintain the flume and wash water at a temperature between 15 to 20°C. The condenser water contains dissolved organic vapors and a small amount of ammonia.

Pulp Screen Water

Much of the water remaining in the beet slices or "cossettes" after extraction of sugar is removed from the spent material by screening. A portion of the pulp screen water is used for fluming ashes from the furnaces. The latter portion, after the ashes are allowed to settle out, is screened and then discharged to the main sewer with the balance of the pulp screen water. The pulp screen water is considerably less in volume than flume water but carries a greater concentration of organic materials. The wastes include dissolved sugar, protein, salts, pectin, cellulose, pentosans, and other organic materials.

Pulp Press Water

Before the screened pulp enters the dryer, it is pressed to remove as much liquid as possible before drying for cattle feed. The pulp press water, at time of study, was being discharged to the drain ditch by means of a 12-inch tile sewer.

Lime Cake Wastes

Lime cake is the precipitate filtered out of the lime-treated and carbonated juice. The cake, diluted with water, is pumped as a slurry to the main plant sewer. On a dry basis, the lime cake will average about 50 pounds per ton of beets sliced. This waste, besides the calcium carbonate, contains considerable organic matter as sugar, organic nitrogen, phosphates and other compounds.

Miscellaneous Wastes

Floor washings and washings from filter cloths are returned for reprocessing if they contain sugar, otherwise they are wasted to the sewer.

Waste Disposal Practices

Receiving Stream

The irrigation ditch passing through the plant property supplies the processing water and is the ultimate recipient of the treated and untreated plant wastes (figures 3 and 4). About 8 c.f.s. are diverted for processing needs, a good portion of which is ultimately returned to the ditch. The ditch parallels the main plant sewer canal and then runs adjacent to and east of the treatment field (figures 3 and 5). The field and drain ditch are separated by a dike for the full length of the field, about 3,500 feet. A collection channel at the lower end of the treatment field discharges to the ditch which flows into the North Platte River about one mile distant at this point. The drain is a clear water stream supporting fish life and having year around flow.

Sewerage

Two sewers emanate from the factory. One, a 12-inch tile line, empties directly to the drain ditch about 75 feet below the process water supply diversion dam (figures 3 and 4). The other line, a 27-inch sewer originally discharging to the drain ditch, now empties to a waste canal which conveys the waste to a pump house. The waste canal parallels the drain ditch, being separated by a dike. When the pump is down for maintenance, the main factory wastes are by-passed directly to the drain ditch.

The pump that lifts the wastes to the treatment field distribution flume is rated at 3,500 gallons per minute. The pump house well has an overflow to the drain ditch.

Natural Grassland Treatment Field

The field consists of 160 acres as depicted in figures 2, 4, and 5. It is roughly rectangular in shape, 3,500 feet long and 1,750 feet wide at the inlet end.

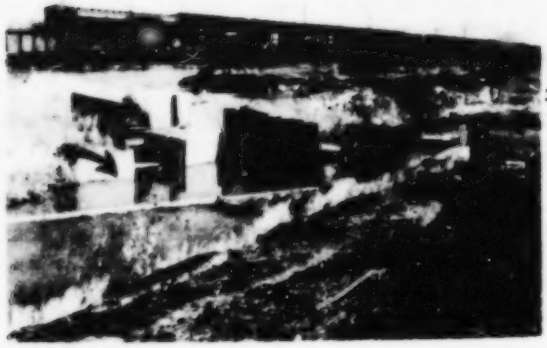
Application of waste to the field is by a distribution flume having a dirt bottom and wood sides; the outlets from the flume to the field are 4-inch pipes spaced at 25 feet intervals (see figures 2, 3, and 4). The structure, except for the dirt bottom, was apparently well designed

hydraulically, but the distribution pipes require diligent maintenance to prevent clogging by accumulated beet tops. Erosion of the bottom of the flume caused by eddying currents around the clogged outlets frequently developed into complete washouts of the dike supporting the flume.

The natural grassland field, essentially ungraded, is generally level, but not level enough to prevent channeling. Only a limited portion of it could be truly called a "grassland filter" with the waste passing through the grass in shallow sheets. The lack of uniform distribution combined with channeling reduced the effective area and permitted excessive short circuiting through the field. As the natural flow of the waste over the field reaches the lower end, it is collected in the effluent canal and discharged to the drain ditch.

Figure 3

D-1
Water
Intake

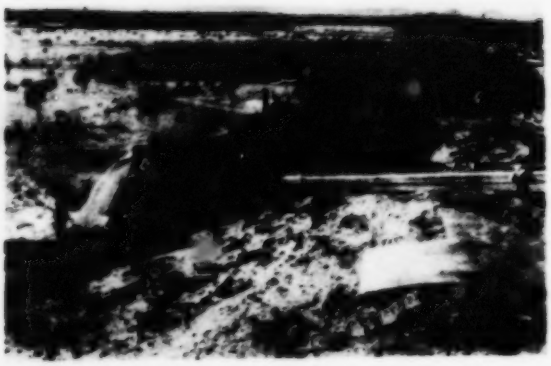


S-1 - 12-inch sewer entering drain ditch

Bayard Sugar Factory Drain

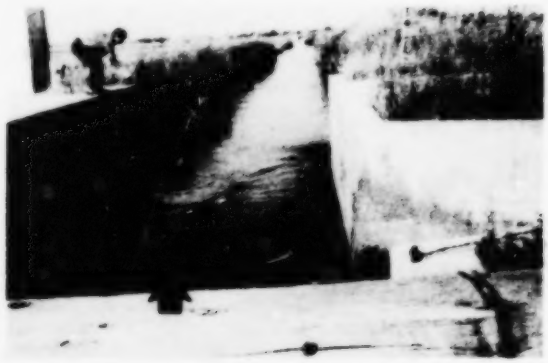
D-3
Drain
ditch

F-5 - field effluent



Distribution header showing discharge pipes
(Note flume replacing pipes)

Treatment field effluent discharging to
drain ditch



Sampling and gaging station (D-4) Drain Ditch
below treatment field

OBJECTIVES

The aims of this study are briefly outlined as follows:

1. To evaluate the over-all effectiveness of the grassland field treatment of beet sugar wastes.

2. To evaluate treatment accomplished in various segments of the field.

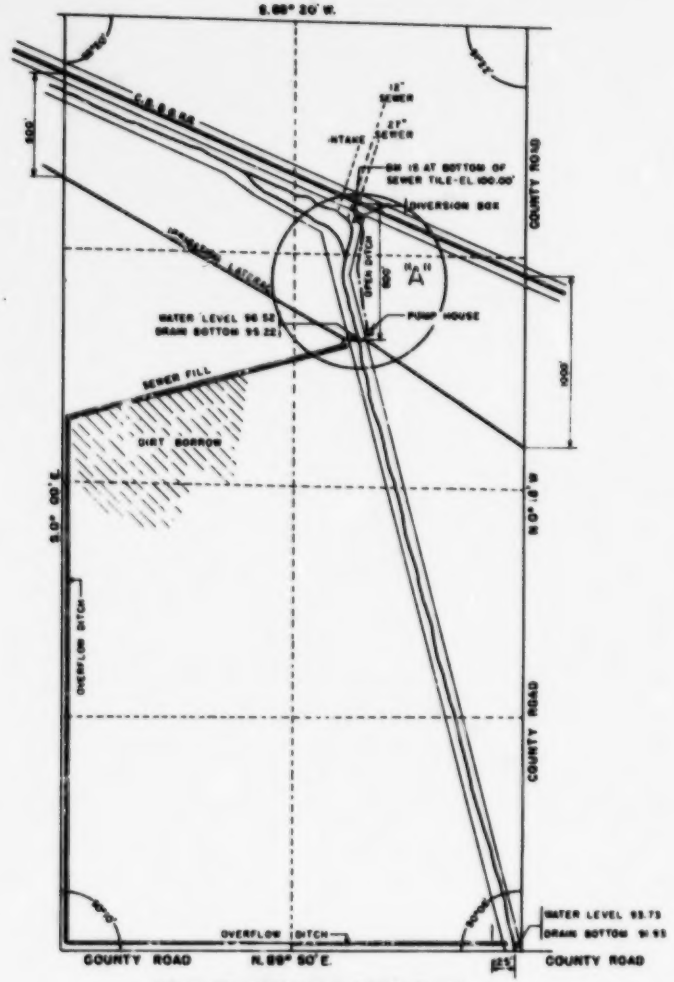
3. To determine the effect of the field effluent on the receiving drain ditch and on the North Platte River.

4. To evaluate grab versus composite sampling of the beet sugar wastes and treated effluent.

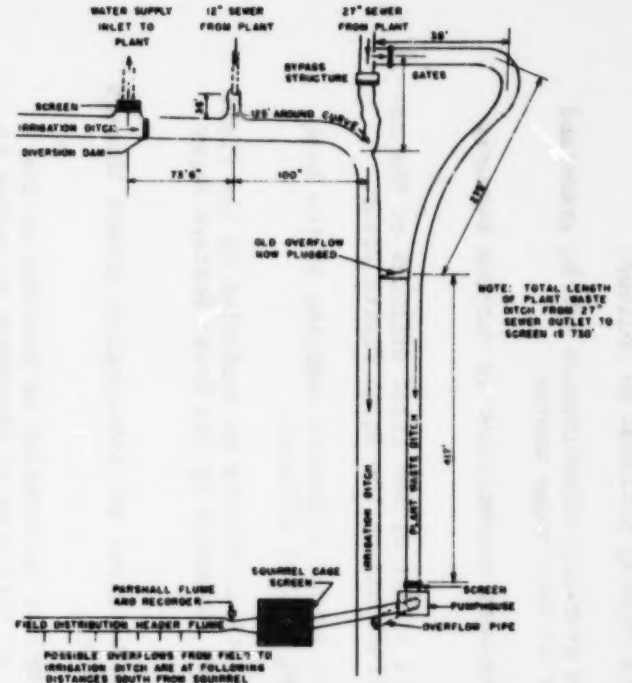
5. To evaluate analytical results as conducted by the field team versus those conducted by the Great Western Sugar Company.

6. To record bacteriological and limnological trends through the treatment area.

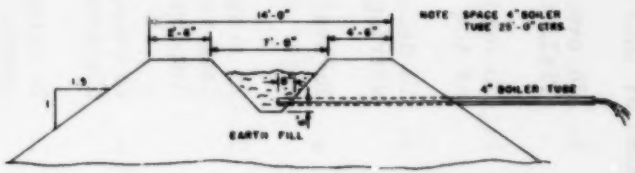
7. To obtain as complete information as possible on the characteristics of this type of treatment as needed to evaluate its suitability for use at other plants.



DRAIN AND WASTE CANAL RIGHT OF WAY
C.B. & Q. R.R. RIGHT OF WAY
SCALE 1" = 400'


WATER SUPPLY INLET TO PLANT
12" SEWER FROM PLANT
27" SEWER FROM PLANT
BYPASS STRUCTURE
GATES
SCREEN
IRRIGATION DITCH
DIVERSION DAM
125' AROUND CURVE
73'6"
100'
OLD OVERFLOW NOW PLUGGED
NOTE: TOTAL LENGTH OF PLANT WASTE DITCH FROM 27" SEWER OUTLET TO SCREEN IS 750'
PLANT WASTE DITCH
IRRIGATION DITCH
SQUIRREL CAGE SCREEN
PARSHALL FLUME AND RECORDER
SCREEN
PUMPHOUSE
FIELD DISTRIBUTION HEADER FLUME
OVERFLOW PIPE
POSSIBLE OVERFLOWS FROM FIELT TO IRRIGATION DITCH ARE AT FOLLOWING DISTANCES SOUTH FROM SQUIRREL CAGE SCREEN:
660' OCCASIONAL OVERFLOW BECOMING LARGER
900' OVERFLOW WITH 3" RISE IN WATER ELEV.
920' " " " " " "

SCHEMATIC DETAILED DRAWING AREA "A"



TYPICAL SECTION- SEWER DITCH

WASTE DISPOSAL FACILITIES
AT
GREAT WESTERN SUGAR COMPANY
BAYARD, NEBRASKA
FIGURE 4

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
DIVISION OF WATER POLLUTION CONTROL
MISSOURI DRAINAGE BASIN OFFICE
OCT 21, 1953

SURVEY PROCEDURE

Field data were accumulated by an intensive study for approximately one month starting October 19, 1953, and by supplemental evaluations conducted by the Great Western Sugar Company. Plant operation and processes were observed.

Sampling stations were established at the plant raw water supply, sewer lines, inlet and outlet of the treatment field, various segments within the field, along the drain ditch and along the North Platte River. Physical, bacteriological, and chemical tests were conducted. Routine samples included grab and 8, 10, and 24 hour composites, the composites being collected in increments spaced at 2 hour intervals. Samples composited from individual samples collected, for example, at 6, 8, 10, and 12 o'clock were termed 8-hour composites; each of the 4 samples was considered to represent 2 hours of operation. Those tests that required immediate analyses, such as dissolved oxygen and bacteriological determinations, were conducted on grab samples only.

Climatological data were collected to ascertain the effect of these factors. In addition, flow studies to determine flow characteristics of the field and a brief limnological investigation were made.

Sampling Stations

The sampling stations are tabulated in table 1 with their location and description, type of sampling and pertinent comment. In addition, the stations are shown in figures 2 and 3. Sampling stations of the treatment field are depicted in figure 5.

The drain ditch was sampled at the factory water supply diversion to establish data relative to raw water quality and to provide a reference point for evaluation of the effects of untreated factory waste and treatment field effluent upon the ditch as detected by the series of downstream stations. The main factory wastes were sampled at the distribution header prior to waste application to the treatment field. The intermittent operation of the lift pump probably has an influence on the sampling and flow recording at this station. It is believed that the flow was probably greater than recorded. Station F5, the treatment plot effluent at the discharge flume, was an excellent point for accurate flow measurement and representative sampling.

Adequate sampling of the treatment field offered a considerable challenge. As a starting point, it was decided to sample first at quarter points longitudinally - 900, 1,800, and 2,700 feet from the distribution header - with 3 transverse stations equally spaced or in free flowing channels depending upon specific conditions in the field. The transverse samples were generally composited for a single quarter section analyses. Additional three station transect sampling was instituted at longitudinal points 300. 450, 600, and 1,350 feet from the distribution header. These are depicted in figure 5.

To permit adequate control of the flow studies, the treatment field was staked in 200 foot squares and each stake marked. By use of a

Table 1. Sampling Stations

No.	Location: Description	Location: River Miles above Mouth	Sampling	Remarks
F-1	Influent to field - factory waste collected at flume in distribution header		Grab: 8, 10 and 24 hr. composites	
F-300	Field - 300 feet from distribution header		Transect 8 hr. composites	
F-450	Field - 450 feet from distribution header		Transect 8 hr. composites	
F-600	Field - 600 feet from distribution header		Transect 8 hr. composites	
F-900	Field - 900 feet from distribution header		Transect 8 and 10 hr. composites	Treatment field reference F-2
F-1350	Field - 1350 feet from distribution header		Transect 8 hr. composites	
F-1800	Field - 1800 feet from distribution header		Transect 8 and 10 hr. composites	Treatment field reference F-3
F-2700	Field - 2700 feet from distribution header		Transect 8 and 10 hr. composites	Treatment field reference F-4
F-5	Field effluent		Grab: 8, 10 and 24 hr. composites	
S-1	Factory waste from separate 12-inch sewer collected at discharge to drain ditch		Grab: 8, 10 and 24 hr. composites	
D-1	Bayard Sugar Factory Drain[1] - Raw Water Intake	1.78 (Est.)	8, 10 and 24 hr composite and grab - Occasional sample to Lincoln for chemical analyses	Above plant waste discharges
D-2	Bayard Sugar Factory Drain - Immediately upstream from waste lift pump	1.75 (Est.)	8, 10 and 24 hr. composite and grab	To evaluate intermediate pollution from 12-inch sewer and possible spillage and seepage
D-3	Bayard Sugar Factory Drain - Immediately upstream from field effluent	1.12 (Est.)	8, 10 and 24 hour composite and grab	
D-4	Bayard Sugar Factory Drain - 3300 feet downstream from field effluent	0.50 (Est.)	8, 10 and 24 hour composite and grab	At U. S. G. S. gaging station
R-1	North Platte River - Shibrow Bridge	MP 159.5	Two channel grab composite	
R-2	North Platte River - 1/2 mile upstream from ditch	MP 155.4 (Est.)	Grab sample from right bank (Frei Dursal Farm)	To show stream conditions immediately upstream from drain ditch
R-3	North Platte River - Rt. 26, Highway bridge, Bayard	MP 154.6	Numerous channels	Station omitted - poor sampling point
R-4	North Platte River - Union Pacific R.R. bridge below Bayard	MP 152.5	Four channel grab composite	Excellent downstream station
R-5	North Platte River - Bolton diversion dam	MP 151.0	Grab from dam at right bank	
R-6	North Platte River - R.R. bridge above Bridgeport	MP 141.8	Grab	Additional intermediate pollution reaches river above this station

[1] U. S. G. S. nomenclature

coordinate system, personnel studying the field and observing the passage of dye were able to orient themselves and to locate and record exact positions. This also facilitated plotting of data in figure 5.

River samples were usually taken from the main channels and composited; dissolved oxygen and coliform concentrations were determined on the individual grabs. R1, R4, and R6 were collected from bridges. R2 was a bank sample yet believed representative because the main channel swept the right shore at this point and the stream was several feet deep. Sampling here was desirable in order to show stream characteristics above the entrance of the drain ditch. The river station south of Bayard, R3, was omitted from routine sampling as flow from the drain ditch hugged the left bank and collections would not indicate possible influence of the factory waste. The remaining downstream stations were typical of river locations with no more than ordinary difficulties associated with accessibility and assurance of representative collections.

Laboratory Tests and Their Significance

Routine laboratory tests included temperature, turbidity, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, settleable solids, coliform group organisms, total bacteria, and solids and volatile matter - total, suspended, and dissolved. Temperature, dissolved oxygen and bacterial analyses were run on grab samples only because time causes appreciable changes in these parameters. Examination and analyses were made in accordance with "Standard Methods for the Examination of Water and Sewage" Ninth Edition, 1946.[8]

Temperature

The temperature of a water is one of the factors which controls the oxygen solubility and thus the saturation level of dissolved oxygen in a stream. The rate of natural purification and bacterial growth is affected by temperature changes.

Turbidity

Turbidity is an expression of the interference of suspended matter to light penetration. Turbidity of a water is due to settleable and non-settleable suspended matter and gives an approximation of the amount of silt or suspended material carried by the water. Turbidity may also result from plankton growths.

Dissolved Oxygen (D.O.)

The dissolved oxygen is that amount of oxygen in a solution usually expressed in parts per million by weight or percent saturation. Normally the amount of oxygen dissolved in water is limited by the saturation value (i.e. 9.17 ppm. at 20°C. and 760 mm. barometric pressure). The elevation at Bayard, Nebraska, is about 3,760 feet with a corresponding reduction in barometric pressure causing the dissolved oxygen saturation value to be approximately 87 percent of that at 760 mm. pressure, or 7.99 ppm. at 20°C. In some cases, as a result of photosynthetic action, this value

may be exceeded, causing supersaturation. Dissolved oxygen must be present to support fish and other aquatic life and for the natural aerobic purification of stream waters. Generally, significant depletions of dissolved oxygen are indications of pollution.

Biochemical Oxygen Demand (B.O.D.)

The B.O.D. of a liquid is the parts per million of oxygen required for stabilization of putrescible organic matter by aerobic digestion. The usual test for B.O.D. requires five days incubation in total darkness at 20°C. of sealed samples of liquid and subsequent determination of the loss of oxygen during that time.

A population equivalent (P. E.) is the B.O.D. usually attributable to wastes from one person and is generally taken as 0.167 pounds of 5-day 20°C. B.O.D. per day.

pH

pH is defined as the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalents per liter. The pH scale (0-14), in common usage, has its neutral point at 7.0; values below 7.0 indicate the presence of acids, those above 7.0 the presence of alkalies.

Alkalinity

Alkalinity is caused by carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates, and is measured by the amount of standard acid required to reduce pH to a known level. In comparison with pH, alkalinity is generally assumed to be a quantity factor while pH is considered an intensity factor.

Settleable Solids

Settleable solids may be defined as the volume of that matter in the liquid which settles under quiescent conditions in one hour.

Coliform Group Organisms

These are a group of bacteria, predominantly inhabitants of the intestine of man and animal but also found on vegetation, including all aerobic and facultative anaerobic gram-negative, nonspore-forming bacilli that ferment lactose with gas formation.

The most probable number (M.P.N.) is that number of organisms per unit volume which, in accordance with statistical theory, would be more likely than any other possible number to yield the observed test results or which would yield the observed test results with the greatest frequency. This value is obtained by testing the bacterial density by the dilution method and is expressed as density of organisms per 100 milliliters.

Total Bacteria

The total bacteria as determined during this study is the 37°C. standard agar plate count. Results are presented in organisms per

milliliter.

Solids

Solids and volatile matter are reported in three groups: total, suspended and dissolved (filtrable). The analyses as conducted by the plant laboratory actually encompassed total and total fixed solids, and dissolved and dissolved fixed solids; other values were calculated therefrom. Normally, the volatile solids are taken to be organic in nature but, with lime wastes, volatilization of carbon dioxide from calcium carbonate results in high volatile solids.

Table 2. Summary of Average Results from Composite Samples

Station	Description	Flow cfs.	Flow mgd	D.O.[1] ppm	B.O.D. ppm	Coliform[2] mpn/100 ml	Bacteria[2] 37° Count	pH	Alk ppm	Turb ppm	Sett. Solids ml./l.	Total Solids ppm	Total Volatile Solids ppm	Suspended Solids ppm	Dissolved Solids ppm
						A. Treatment Field									
F-1	Influent	4.3	2.8	0.97	483	2,100,000	1,200,000	8.5	2,576	2,100	18.2	6,276	2,194	5,215	1,063
F-300	Filter Area	-	-	-	444	2,300,000	145,000	7.8	2,242	1,600	14.0	4,346	1,835	3,152	1,194
F-450	Filter Area	-	-	-	249	930,000	1,125,000	7.6	561	280	1.2	1,096	491	37	1,059
F-600	Filter Area	-	-	-	229	2,300,000	48,000	7.4	472	160	0.3	1,144	533	88	1,076
F-900	Filter Area	-	-	-	194	1,900,000	700,000	7.6	456	110	<0.1	1,056	420	60	1,007
F-1350	Filter Area	-	-	-	128	43,000	690,000	7.8	495	60	<0.1	1,070	414	32	1,050
F-1800	Filter Area	-	-	-	113	930,000	325,000	7.9	476	70	<0.2	1,007	382	52	954
F-2700	Filter Area	-	-	-	147	4,865,000	200,000	7.9	469	60	<0.1	1,004	424	79	984
F-5	Effluent	3.5	2.26	0.44	158	230,000	302,000	7.8	486	75	<0.1	1,005	407	63	941
F-450	% Removal	-	-	-	48	-	-	-	80	87	93	83	78	>99	<1
F-900	% Removal	-	-	-	60	-	-	-	82	95	>99	83	81	99	5
F-5	% Removal	-	-	-	67	89	75	-	81	96	>99	84	81	99	11
						B. 12-inch Plant Sewer (discharge to drain ditch)									
S-1	Plant sewer to ditch	1.6	1.03	1.29	337	5,400,000	3,500,000	6.9	254	1,000	12.5	2,304	1,196	1,056	1,248
						C. Drain Ditch									
D-1	Drain ditch raw water intake	-	-	9.89	2.37	2,300	6,000	8.1	283	30	<0.1	716	216	70	646
D-2	Drain ditch above field	-	-	9.31	32.3	230,000	176,000	8.0	292	95	0.9	-	-	-	-
D-3	Drain ditch above effluent	-	-	7.96	>37.1	590,000	210,000	8.0	304	80	0.7	786	237	92	694
D-4	Drain Ditch below field	37.0	-	5.74	52.4	930,000	460,000	7.9	324	95	0.8	804	228	166	638
						D. River (grab samples)									
R-1	Hebron Bridge	1,160	-	3.84	16.8	230,000	258,000	8.0	370	95	-	-	-	-	-
R-2	1/2 mile upstream from ditch	1,170	-	5.94	18.2	119,000	478,000	8.0	380	110	-	-	-	-	-
R-4	NB Bridge below Bayard	1,220	-	5.39	15.1	93,000	308,000	8.0	360	90	-	-	-	-	-
R-5	Below Diversion Dam	1,290	-	6.46	10.7	-	-	8.0	322	90	-	-	-	-	-
R-6	NB Bridge above Bridgeport	1,440	-	9.17	11.6	-	-	8.0	351	100	-	-	-	-	-

Note:
1 - Grab samples
2 - Grab samples - median value

PRESENTATION OF DATA

The individual physical, chemical, and biological analyses are tabulated in the appendixes. Much of the data have been summarized showing maximum, average, median, and minimum values. Included also as appendixes are the analyses of the chemical characteristics of the water conducted on various samples by the Division of Laboratories, Department of Health at Lincoln, Nebraska; climatological data showing maximum, minimum, and 5:00 p.m. temperatures, evaporation, precipitation, wind velocity and wind direction; and supplemental analyses as conducted by the Great Western Sugar Company as well as data collected by the Company during the 1952 beet sugar campaign. For comparative evaluations average results are used except for the bacteriological data where median values are employed.

Plant Wastes

Two sewers discharged wastes from the Bayard plant. Both were gaged and the following results obtained for the period of study: the 12-inch tile line that emptied to the ditch had an average discharge of 1.6 c.f.s. with a B.O.D. of 337 ppm. and 1,056 ppm. suspended solids; the main plant outfall had an average flow of 4.3 c.f.s., as measured at the field distribution flume, with 483 ppm. B.O.D. and 5,215 ppm. suspended solids. These data are summarized in table 2. Other analyses are given in appendix II. The population equivalent based on B.O.D. of these two discharges combined is 84,600 (table 3). Approximately 14,400 population equivalents reached the drain ditch by overflow or seepage where the waste canal parallels the ditch prior to sampling station F1, as ascertained by ditch sampling, and must be added to the previous measured values. Thus the population equivalent of waste from the plant approximated 99,000. Based on an average daily cut of 1,890 tons of beets, the population equivalent per ton of beets was 52.4. The average daily suspended solids load as discharged by the two sewers was 131,000 pounds of which 121,900 pounds were in the main sewer discharging to the treatment field.

Treatment by the Grassland Field

Table 2 includes the F. series sampling stations, i.e., the influent to the treatment plot, the sectional sampling of the grassland field and the effluent. The average B.O.D. of the influent was 483 ppm. and of the effluent 158 ppm., a reduction of 67 percent. Suspended solids were reduced 99 percent from 5,215 ppm. to 63 ppm. The over-all efficiency of the treatment plot might be better illustrated by reference to table 3 showing pound values. It will be noted that the average volume of the influent applied to the field during the period of study was 4.3 c.f.s. while the effluent was 3.5 c.f.s. Of the 11,200 pounds of B.O.D. applied daily to the field 2,990 pounds were discharged in the effluent, a total reduction in B.O.D. of over 73 percent.

The Great Western Sugar Company conducted limited studies during 1952 (appendix VII). Average B.O.D. reduction in ppm. at that time was reported as 57 percent and suspended solids removal over 99 percent which compares reasonably well with current data.

Table 3. Results Showing Average Values in ppm and Pounds Concentrations of Various Parameters, and Population Equivalent Based on B.O.D.

No.	Station	Flow c.f.s.	B.O. ppm	B.O. lbs.	B.O.D. ppm	B.O.D. lbs.	B.O.D. P.E.	Suspended Solids ppm	Suspended Solids lbs.
D-1	Ditch - below water supply intake	31.1 (Est.)	9.89	1,660	2.37	398	2,390	70	11,750
S-1	Sewer to ditch	1.6	1.29	11	337	2,910	17,450	1,096	9,130
D-2	Ditch immediately above field	32.7 (Est.)	9.31	1,640	32.3	5,700	34,200	-	-
F-1	Factory effluent to field	4.3	0.97	22	485	11,200	67,200	5,215	121,900
D-3	Ditch before receiving influent	32.7 (Est.)	7.96	1,405	>37.1	>6,550	>39,300	98	16,262
F-5	Field effluent	3.5	0.44	8	158	2,990	17,950	63	1,190
D-4	Ditch downstream	37.0	5.74	1,147	52.4	10,470	62,680	166	33,167

Table 4. Channel Sampling in Grassland Field - 8 hr. Composites

	Date	Flow cfs	Flow mgd	B.O. ppm	B.O.D. ppm	Coliform ml./l.	Bacteria 37°Count	pH	Alk. ppm	Turb. ppm	Set'l. Solids ml./l.
					Left Channel						
F-450	Nov. 10	-	-	0.43	480	-	-	7.8	1,344	1,400	9.5
F-900	Nov. 9	-	-	-	397	-	-	7.5	478	230	<0.1
F-1800	Nov. 6	-	-	0.0	228	-	-	7.5	518	140	0.1
F-2700	Nov. 5	-	-	1.27	228	-	-	7.8	474	90	<0.1
					Middle Channel						
F-450	Nov. 10	-	-	0.74	534	-	-	7.5	1,696	1,700	14.0
F-900	Nov. 9	-	-	-	296	-	-	7.1	465	310	<0.1
F-1800	Nov. 6	-	-	1.29	185	-	-	7.6	488	85	<0.1
F-2700	Nov. 5	-	-	1.52	185	-	-	7.8	518	75	<0.1
					Right Channel						
F-450	Nov. 10	-	-	0.0	334	-	-	7.7	444	270	0.1
F-900	Nov. 9	-	-	-	292	-	-	7.3	466	140	<0.1
F-1800	Nov. 6	-	-	1.43	87.3	-	-	8.1	514	40	<0.1
F-2700	Nov. 5	-	-	1.28	191	-	-	7.8	481	75	<0.1

Table 5. Comparative Laboratory Analyses Station

Date	Station	DO-ppm U.W.[1]	DO-ppm U.S.P.H.S.[2]	BOD-ppm U.W.	BOD-ppm U.S.P.H.S.	pH U.W.	pH U.S.P.H.S.
	F-1 Plant Effluent						
10-21	Grab	-	-	787	519	9.30	8.7
11-6	8 hr. composite	0.71	1.33	673	514	9.05	8.8
	F-2 1/4 sectional sample						
10-21	Grab - 1/2 section	-	-	312	242	7.4	7.2
	F-3 1/2 sectional sample						
10-21	Grab - 1/2 section	-	-	212	203	7.65	7.4
	F-5 Field Effluent						
10-21	Grab	-	-	143	97.1	7.90	7.6
11-6	8 hr. composite	0.58	1.09	194	132	8.05	8.0
	D-1 Drain Ditch - water supply						
10-21	Grab	-	-	4	1.28	8.6	7.9
11-6	8 hr. composite	9.97	10.16	2	1.39	8.4	8.0
	D-4 Drain Ditch below field effluent						
11-6	8 hr. composite	6.22	6.96	52	46	8.25	8.0
	D-2 River above factory outlet						
10-21	Grab - South Bank	-	-	16	11.4	8.4	7.9
11-6	Grab - South Bank	-	6.93	10	14.1	8.35	8.1
	D-6 River B.R. bridge at Bridgeport						
10-21	Grab	-	-	13	8.56	8.4	7.9
11-6	Grab	8.48	9.17	11	14.6	8.35	8.1

1. Great Western Laboratory at Loveland, Colorado
2. U.S. Public Health Service field laboratory, Bayard, Nebraska

It is pertinent to consider results of the sectional field sampling stations. Noting B.O.D. data in table 2, at 300 feet down field, no appreciable reduction took place; at 450 feet, the reduction was 48 percent; at 600 feet, the data indicated a slight increase while at 900 feet the removal was 60 percent. The B.O.D. varied because of field sampling conditions as additional down field results are observed. At 2,700 feet and at the effluent line, B.O.D. values of 147 and 158 ppm. respectively were obtained.

Other parameters depict a like picture; settleable solids in ml. per liter at the influent were 18.2; 14.0 at 300 feet; 1.2 at 450 feet; 0.3 at 600 feet; and less than 0.1 at 900 feet and most down field stations. Alkalinity dropped 81 percent and the total solids 84 percent. Turbidity removal was 96 percent and suspended solids 99 percent. The dissolved oxygen in the effluent was negligible.

The effect of the treatment field on solids is quite apparent. Total solids removal was 83 percent in 450 feet and 84 percent over the entire field; dissolved solids removal was slight, reaching only 11 percent over the field. Suspended solids removal, the fraction that accounts for most of the solids removal, was over 99 percent in 450 feet and the same for over-all removal. It is evident that the suspended matter dropped out of the liquid very rapidly in the upper portion of the field. Treatment appears to be primarily a matter of removal of settleable solids in the upper one-eighth of the field with subsequent biological removal of about 10 percent of the dissolved solids as the waste passed over the rest of the field. The settleable solids test also indicated effective removal of greater than 99 percent within the upper 900 feet.

The bacteriological results in the field were erratic, as anticipated. Prior to the campaign the field was used for grazing by cattle and numerous prairie dogs inhabited the tract. Fecal matter from these animals contaminated the ground and no doubt influenced the bacterial results. The coliform results varied considerably, yet the over-all median reduction was recorded at 89 percent. The total 37°C. bacteria count showed a constant downward trend with an over-all reduction of 75 percent.

To further depict the effect of treatment through the plot, composite samples were collected of individual transect stations as illustrated in figure 5. These results are shown in table 4. Again will be noted the trend for rapid reduction in B.O.D. and solids in the upper portion of the field.

Application of sugar beet wastes to a natural grassland plot appears to be an effective method of reducing pollution. With regard to the Great Western Bayard sugar factory waste, such treatment would seem to be entirely adequate if applied to all wastes emanating from the plant. The use of broad field application for beet sugar waste treatment should be considered for installation at other factories in the North Platte valley and elsewhere where the degree of treatment provided by this method will be compatible with available dilution water.

Biological Features

A biological study of the area was conducted November 1 - 3, 1953, inclusive. Aquatic life in the treatment field consisted mainly of the sewage fungus, Sphaerotilus, and a unicellular green alga, Chlamydomonas. The fungus was attached to grass stems and leaves, mainly in the flow channels, and large areas were blanketed with its long grayish streamers. The algal growths occurred as free swimming forms in suspension, but their greatest concentrations were found adhering to grass and other bottom materials in quieter areas, and in a few instances to filament of fungus. The two growths infrequently occurred in the same areas of the field. Some shifting of current paths occurred, and frequently algal growths were subjected to the maximum velocity of flow observed in the middle and lower parts of the area. Occurrence of algae with fungus was in regions with observable current. Areas with greateast algal concentrations were of vivid green color, areas with fungus growths and channels carrying the greatest load of effluent were gray, while many side areas were covered with clear brown water.

Chemical analyses showed oxygen to be present in small amounts (1.6 - 2.4 ppm.) only in the clear brown water. This water formed a small part of the field effluent, as it trickled into the collection ditch from wide areas, and was in all probability responsible for the minute quantities of oxygen (0.1 - 0.2 ppm.) that were occasionally noted in the effluent. Absence of oxygen in the green areas was apparently the result of immediate exhaustion of quantities produced by photosynthesis, as the algae concerned did not appear to be existing as saprophytes. Nitrogen cycle analyses of water collected in various areas showed greatest concentration of ammonia and nitrate nitrogen (4.0 ppm. NH -N, 0.05 NO_3 -N) in areas with the algal growth. Nitrate content of water in the ditch above the area was far greater than that found anywhere on the disposal area (1.5 ppm. NO3-N). Nitrite nitrogen occurred in the ditch but was absent in water on the field.

The presence of greatest available nitrogen compound concentration in areas with densest algal growth is not coincidental. The grayish turbid water flowing down from the upper end of the field contained much smaller amounts of measurable nitrogen compounds, which indicated that greater nitrogen content in green quiescent areas resulted from biological action. It is probable that the process was bacterial nitrification and that algae were able to thickly inhabit the areas partly as a result of this activity.

Concentration of algae in suspension over different areas of the field varied widely. The effluent, which maintained the grayish turbid appearance the waste water possessed after initial sedimentation in the upper end of the field, contained an average concentration of 66,500 Chlamydomonas per ml. Water over the green algal area varied from 775,000 to 1,650,000 Chlamydomonas per ml; grayish water flowing around algal areas and over fungus areas possessed 64,000 Chlamydomonas per ml; and the areas of clear brownish water contained no suspended organisms. Concentration of algae adhering to the substratum was much greater than that of suspended individuals, and was estimated to amount to approximately 23,000,000 per square centimeter of surface in green areas. When the great area of surface offered by grass blades and stems is considered,

concentration was very great indeed.

The ditch that supplied water for the refinery and received lower down the effluent from the treatment area had a varied algal population, mostly displaced benthic diatoms. To this assemblage was added Chlamydomonas from the treatment area. Average concentration of Chlamydomonas at Station D4 was 337 per ml. As dilution afforded in the ditch was roughly 10 to 1, this concentration was about 1/20 of what would be expected to result from dilution alone. One sample taken about 150' below the treatment area outfall contained 5,003 Chlamydomonas per ml. These facts indicated a rapid die-off of this green alga in the ditch.

Above entrance of wastes from the factory (S1), the ditch contained dense attached growths of Cladophora, a filamentous green alga, along the strands of which were attached many diatoms. Photosynthesis by these algae resulted in supersaturated oxygen levels during daylight hours; and algal respiration continuing after cessation of photosynthesis at dark resulted in oxygen decline during the night. Oxygen saturation noted in early afternoon of November 1 and November 2 was approximately 125 percent. At night (early A. M.) oxygen declined to less than 90 percent saturation.

Other Forms of Life

In addition to Sphaerotilus and Chlamydomonas the microscopic life found in waters over the field contained Paramecium caudatum, Oxytricha fallax, and Vorticella sp. Adult beetles of the Families Hydrophilidae and Dytiscidae, water boatmen (Hemiptera, Corixidae), mayfly nymphs, damsel fly nymphs, and scuds (Hyallella) composed the observed macrofauna. The adult aquatic insects probably flew to the area from nearby permanent habitats; and their air breathing habit permitted their occurrence in all regions of the lower treatment area. The immature insects (nymphs) and scuds were observed only in clear water areas and collection ditch. Their presence in those areas indicated no significantly intolerable conditions when wastes had a few days retention, which was apparently necessary for production of clear water areas.

Experiments

Large samples of field effluent were collected on November 15, 1953, and transported to Kansas City, where they were transferred to glass pans on November 19. Depth in the pans varied from 1½ to 4 inches. Beginning November 23, chemical and biological analyses of water and bottom growths were conducted at intervals until December 18. Water temperature varied from 20 - 21°C. over this period. On November 23 a supersaturated oxygen condition (142 percent) was evident in allpans, and the algal growth, which had at first consisted entirely of Chlamydomonas, had become quite varied. Chlamydomonas was evidently on the decline and diatoms of the genera Nitzchia and Navicula, as well as two green algae (Ankistrodesmus and Chlorella) and Euglena were increasing rapidly. This trend continued. On December 8 Chlamydomonas was relatively rare and diatoms and the two green algae listed above were by far predominant. Euglena had also continued to increase and was about three times as numerous as Chlamydomonas.

Monocarbonate alkalinity eventually increased to 108 ppm. and

bicarbonate alkalinity declined from an original 412 ppm. to 236 ppm. In relation to these alkalinity changes, pH reached a maximum of 9.3. Ammonia nitrogen increased from 0.45 to 1.65 ppm.; nitrite was never present; and nitrate nitrogen increased from 0.02 to 0.2 ppm. Phosphorous was never evident in the available or soluble form. Supersaturated oxygen levels were evident at all times of analyses, which were restricted to daylight hours. These data are presented in appendix IV.

Discussion of Biological Features

Although the algal growths scattered over the treatment area were not observed to add any oxygen that persisted on even a temporary basis, the growth of various forms of life must have been at the expense of materials in the sugar beet wastes, which were utilized in formation of protoplasm as well as in metabolic processes. Concentrations of the fungus growth were not estimated, but the algae adhering to the substrate were very densely developed. The protozoa and their bacterial food organisms developed also at the expense of materials contained in the waste water. Elements required to develop and maintain varied forms of life were taken from the wastes. This additional purification, as measured by B.O.D., seemingly approached 10 percent of the original concentration.

Green areas by virtue of their bacterial and algal content were apparently more effective in removing dissolved substances than the regions containing Sphaerotilus, although the latter were undoubtedly involved in carbohydrate removal. Restriction of green algal areas to rather scattered regions was apparently a result of shifting of flow paths and short circuiting in passage across the field. Establishment of a uniform course of flow involving most of the area, and a rather uniform depth of about 3 inches, would greatly enhance conditions for algal and other growths and probably result in additional reduction of waste compounds.

Effect of Wastes on Receiving Waterways

The effect of the plant waste, both untreated and treated, on the drain ditch is illustrated in table 2. The drain ditch water, where the factory supply is drawn off, had an average of 9.89 ppm. D.O., a B.O.D. of 2.37 ppm., and a median coliform MPN of 2,300 per 100 ml. At station D2, about 200 yards below the 12-inch sewer outfall which discharges untreated wastes, the D.O. dropped to 9.31 ppm., the B.O.D. increased to 32.3 ppm. and coliform increased to 230,000 per 100 ml. At station D3, the average D.O. decreased to 7.96 ppm., the coliform numbers increased, and the B.O.D. increased to 37.1 ppm. At station D4, about one half mile below the treatment field, the waste in the ditch plus the field effluent caused a reduction in D.O. to an average value of 5.74 ppm. and a further increase in B.O.D. to the substantial average of 52.4 ppm. The minimum recorded D.O. value at D4 was 4.19, which is below the 5 ppm. level established as desirable for nontrout waters in the Missouri Basin by the Engineering Section, Missouri Basin Health Council (10). The short flow distance from D4 to the Platte River may well preclude the occurrence of oxygen depletion. It is probable, however, that discharge of all plant wastes untreated to the ditch would have caused a situation approaching nuisance conditions in the lower reaches of the ditch.

At R1 the average dissolved oxygen was 3.84 ppm. but recovery of the stream with concurrent reaeration raised this value to 5.94 ppm. at R2. This action was reversed and the D.O. dropped to 5.39 ppm. at R4 (table 2) indicating the utilization of dissolved oxygen by introduced organic wastes. The downward trend was reversed at station R5 and the dissolved oxygen content continued to increase at R6.

To more clearly show the dissolved oxygen picture, the results of R4 have been evaluated by channels (see appendix I). The river was sampled at four main channels at this station. Significantly, the channel on the extreme left, the side where the drain ditch enters, had an average D.O. of 4.90 ppm. as compared to a D.O. of 5.65 ppm. of the right channel. Also, the minimum D.O. of 3.65 ppm. occurred in the extreme left channel. The results of river sampling compared reasonably well with a study of the North Platte River conducted by the State Health Departments of Nebraska and Wyoming and the Missouri Drainage Basin Office, Public Health Service, in 1950.[7]

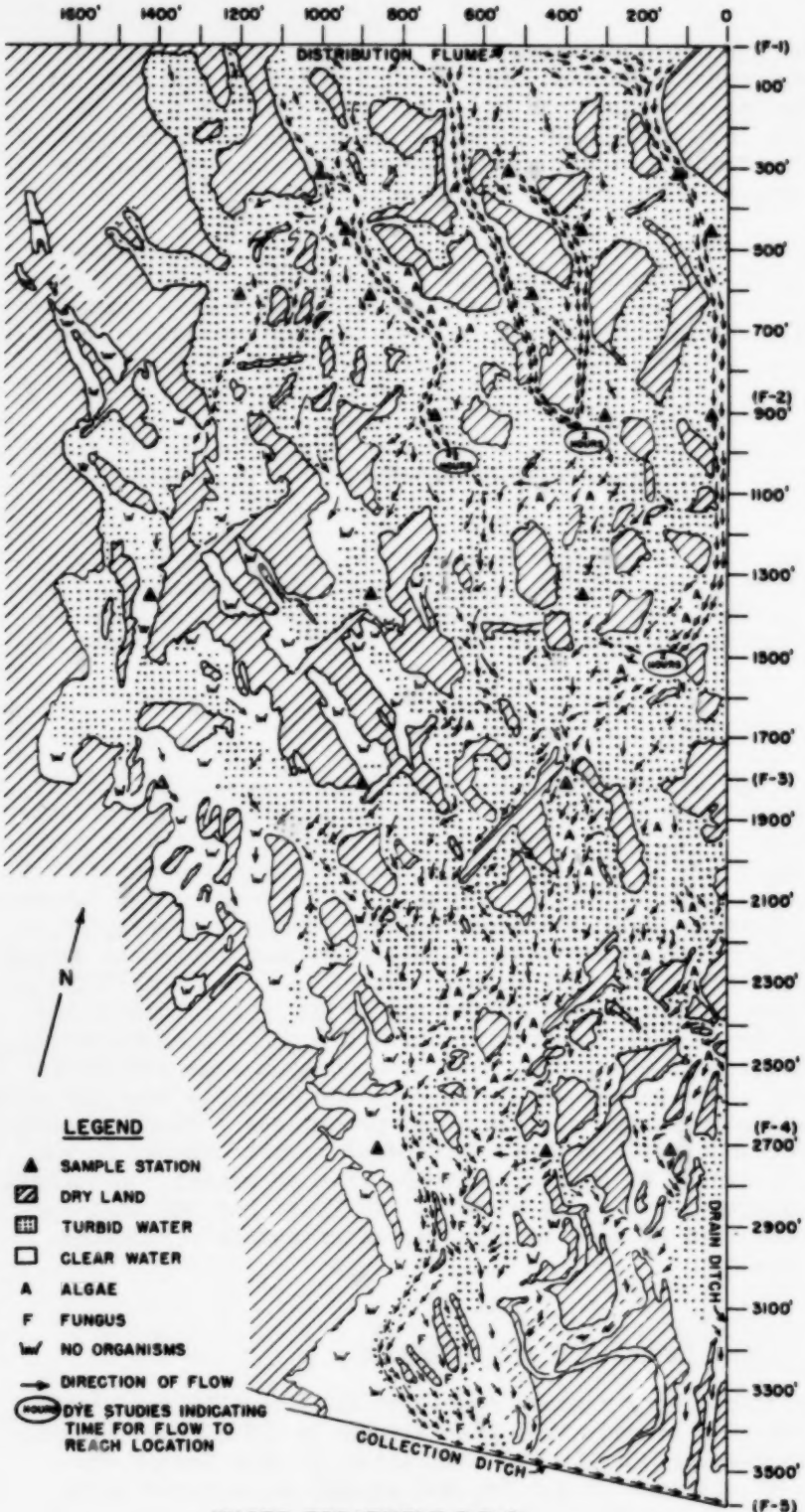
It is believed that if all wastes emanating from the Bayard plant were applied to the grassland filter, sufficient treatment would be provided to preclude the occurrence of detrimental conditions from this source under flow conditions normal to the beet sugar campaign season.

Comparative Laboratory Analyses

On October 21 and November 6, field sampling was conducted jointly with representatives of the Great Western Sugar Company and the duplicate samples were analyzed by the field laboratory at Bayard operated by personnel from the Public Health Service and by the Great Western Laboratory at Loveland, Colorado, about 125 miles distant.[7] These comparative laboratory analyses are shown in table 5. A comparison indicates discrepancies that appear significant. Dissolved oxygen values in many instances varied considerably as did the B.O.D. For example, the B.O.D. tests on F1, October 21 showed 787 ppm. by Great Western and 519 by the Public Health Service, while on November 6, the same tests showed 673 and 514 respectively. Of course, the character of the B.O.D. test is such that some variation may be expected, yet these values would indicate the possible need for more careful sampling and correlation of laboratory procedures. There appears to be a tendency for the B.O.D. analyses conducted by the Company to run higher than those conducted by Public Health Service personnel. Considering the dissolved oxygen test, it is essential for best results that the determination be conducted as soon as possible after sample collection, preferably in the field.

Grab Versus Composite Samples

The fact that beet sugar factory operation is generally continuous has led to the assumption by many that grab samples would adequately provide representative results. A limited evaluation of this factor was made, particularly at stations F1 and F5, and attention is directed to the summary of individual results in the appendix I where the data were separated into two groups, those from composite samples and those from grab samples. Generally, average, and median values also, of the two



WASTE TREATMENT FIELD
GREAT WESTERN SUGAR COMPANY
BAYARD, NEBRASKA
NOVEMBER 11, 1953
FIGURE 5

groups were reasonably comparable where a considerable number of a test were conducted. The maximum and minimum values of the grab samples showed greater extremes. The longer the period of compositing, the less is the variation from the average or median value. For example, the B.O.D. results of F1 are quite typical:

	Grab	8 - 10 hr. Composite	24 hr. Composite
No. of Samples	15	13	3
Maximum	1,083	746	495
Average	496	493	432
Median	423	472	426
Minimum	208	252	375

It would appear that for occasional sampling, 24 hour composites are the most reliable.

Odor

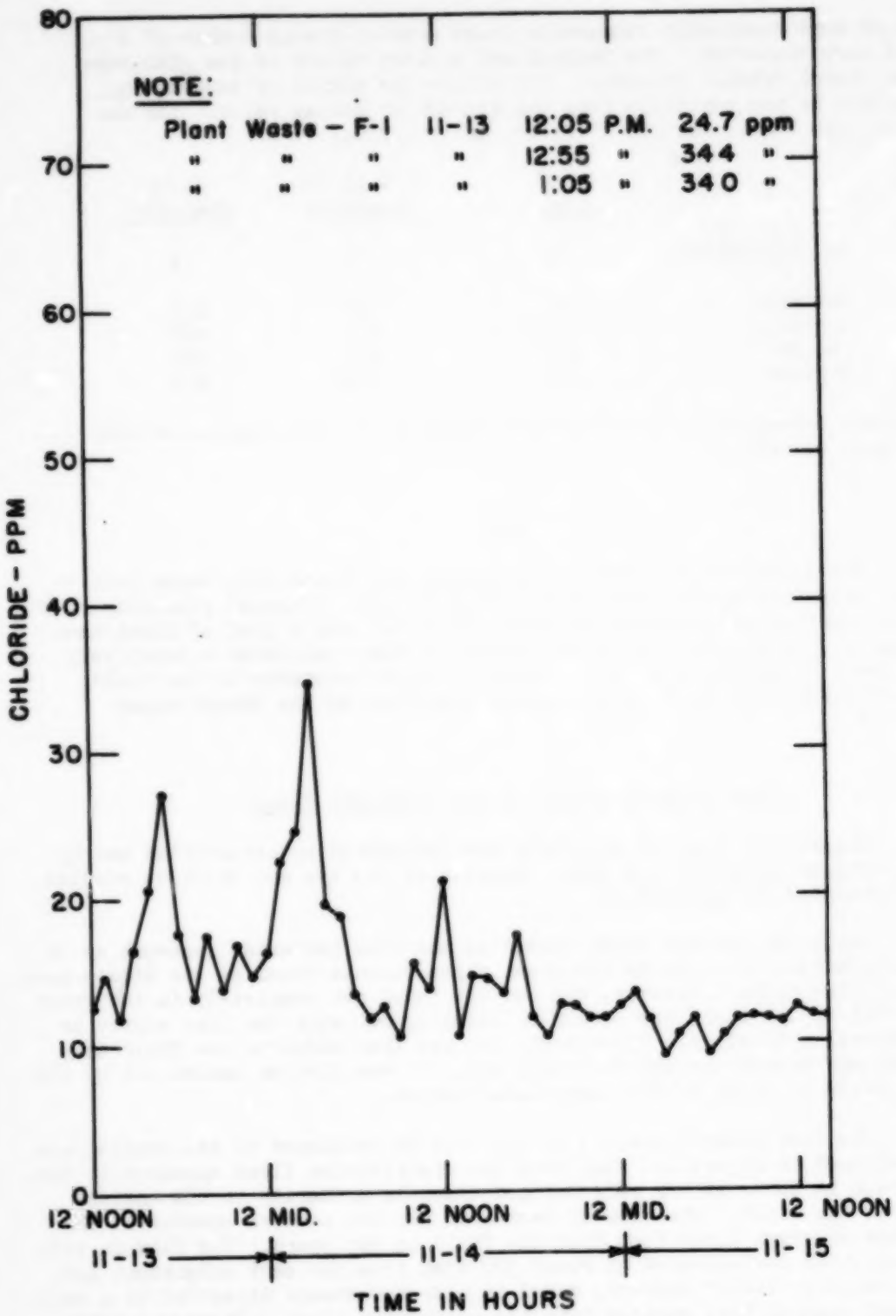
The objectionable odors occasionally associated with sugar beet plant operation may be invariably traced to waste disposal practices. The prevention or reduction of these odors has been a goal of plant management. Observation during the period of study indicated a relatively low level of atmospheric odors except in close proximity to the field, a factor favoring the disposal method practiced at the Bayard sugar factory.

Flow Characteristics of the Treatment Field

The flow pattern of the field was determined by observation and by flow studies using dye and salt. Results of the dye and chloride studies are tabulated in appendix IV.

Congo red dye was first chosen as the flow indicator inasmuch as it was a contrasting color to the green algae reaches found in the middle portion of the field. However, the red dye faded out completely in the first 500 feet of the field due either to settling out with the lime slurry or to excessive dilution. Fluorescein dye was then added to the field influent and traced through the field until it was lost or masked out by the similarity in color of the algae-laden waters.

The flow characteristics of the plot as developed by the studies are illustrated in figure 5. Flow from the distribution flume appeared to concentrate in three rather well defined channels primarily in the eastern half of the field. One channel seemed to hug the eastern embankment and dye was observed 1,500 feet down the field in two hours. The flow in this channel then concentrated at about 500 feet from the east embankment and, in a swiftly flowing current, moved in a southwestward direction to a well defined channel that emptied into the collection ditch. There was little doubt that portions of the flow could seep through the field in about 5 hours.



CHLORIDE CONCENTRATIONS AT F-5 (GRASSLAND EFFLUENT) AFTER DOSING PLANT WASTE WITH 1000 # SALT AT 12:40 PM, NOV. 13, 1953.

FIGURE 6

The second principal channel, essentially the middle one, started in the upper part of the field approximately 700 to 800 feet from the east embankment and flowed in a generally southeasterly direction. In two hours, dye was observed beyond 900 feet down the field. The flow then broke to the southwest where it combined with the principal flows from other channels at 1,300 to 1,500 feet down the field.

The third channel started at about 1,125 feet from the east embankment and flowed generally southeast with a small diversion flowing southwest. In 2½ hours, the dye in this channel penetrated over 1,000 feet down the field. The flow was subsequently traced to 1,900 feet where it joined the other channels at about 400 feet from the east embankment.

To determine the over-all detention time of the field, 1,000 pounds of cattle salt (sodium chloride) were added at the pump intake just prior to station F1 and hourly samples collected for 50 hours at the field effluent station F5. Chloride determinations were made on these hourly samples.

The results of the chloride study are shown in figure 6. When the salt was added to the plant waste at 12:40 p.m., the chloride concentration increased from 24.7 to 340 ppm. Effluent samples at F5, collected at the same time, showed chloride concentrations in the neighborhood of 13 ppm. At 5:00 p.m., slightly over 4 hours later, a peak of 27 ppm. chloride was obtained indicating short circuiting and rapid flow of part of the waste. This correlates well with the dye studies. After that, the concentration decreased and then again increased until a maximum of about 35 ppm. chloride occurred at 3:00 a.m., about 14 hours after initial dosage. Secondary peaks of lesser magnitude occurred at 12 Noon and 5:00 p.m. of the following day reaching 21 and 17 ppm. respectively. The chloride concentration leveled off to about 12 ppm., equal to that prior to the introduction of the salt, at 6:00 p.m. of the second day and essentially maintained that concentration with only minor fluctuations for 20 hours until the termination of the run at 2:00 p.m. of the third day.

Considering that the maximum "slug" of salt essentially reached the field at about 1:00 p.m., a considerable portion passed through the field in 4 hours, the maximum concentration reached the effluent in 14 hours and most of the salt cleared the field within 29 hours. The average detention time of waste through the field would then be one-half of 29, or 14.5 hours which coincided extremely well with the maximum concentration detected in 14 hours.

DISCUSSION

Waste Evaluation

The principal wastes from the Bayard plant emanated from fluming and washing of beets, pulp screening, pulp pressing and flushing of the lime cake. Early in the present study, it was observed that a 12-inch sewer discharged plant waste directly to the drain ditch without passage through the treatment field. The Company reported that the sewer carried pulp press water besides ash pit drippage water, sanitary sewage and minor miscellaneous wastes. As indicated in table 3, the waste contained daily 2,910 pounds B.O.D. When based on an average of 1,890 tons processed per day, the B.O.D. amounts to 1.54 pounds per ton. Other studies[2] indicate an average of 2.6 pounds B.O.D. per ton of beets may be expected from pulp pressing. The volume discharged by this sewer is about three times that normally expected from the pressing of pulp. It is quite possible that only a portion of the pulp press water is discharged by this particular sewer and that it contains considerable wash water. It would be desirable to connect this line to the main plant sewer so that all wastes might be treated by application to the grassland field.

The total population equivalent of waste from the plant during the period of study approached 99,000, which is considered low for wastes of this type. The summer and fall were relatively dry in the Platte valley. The harvesting of beets proceeded rapidly with a minimum of adhering soil. The sugar beet campaign started with "Indian Summer" days, warm weather and no freezing. Thus the beets arrived for processing in excellent condition and it would be expected that the wastes would be relatively low.

It has been reported[2] that in waste similar to that discharged at Bayard, the B.O.D. of the lime cake slurry would amount to 56 percent of the total B.O.D. discharged. A 1952 unpublished report by Great Western Sugar Company on the Bayard plant indicated a similar percentage. Other studies have indicated a somewhat lower percentage[4] although recognizing the relatively large portion of this waste on a B.O.D. basis. Because of the polluting material in the lime waste, other possible methods of lime cake disposal should be given serious consideration in any over-all waste disposal problem. At Bayard, the Company decided that economics indicated in favor of hydraulic removal with treatment for B.O.D. and solids removal along with the remainder of the plant wastes. Elsewhere, other solutions may be more advantageous.

The lime cake as removed from the filters is rather dry and could be removed in this state and, under proper circumstances, used for soil conditioning, fill, or even for calcining for reuse. The organic matter in the cake might provide a large part of the fuel necessary. Of course possible odors and other problems attending lime cake handling must always be a consideration. The omission of this material from plant wastes might reduce the B.O.D. and the suspended solids in the neighborhood of 55 percent. It will be noted that the immediate drop out of B.O.D. was 48 percent and that over-all removal of B.O.D. in ppm. through the treatment plot was 67 percent. On the other hand, the lime may act as a precipitant and assist in removal of settleable material. It is felt, however, that where proper settling conditions are provided, this latter factor would be a minor consideration.

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Studies of lime cake use or reuse should be one of the initial steps in any waste disposal program for the beet sugar industry. Another important consideration is reduction in water use. By reducing the strength and volume of wastes produced, the disposal problem may be correspondingly reduced.

Volume Study

It is interesting to endeavor to account for the volume of the liquid wastes as it proceeds from the plant through the waste treatment field. Recognizing that inherent factors of sampling and gaging will not permit absolute comparisons, it is still desirable to show trends and to more clearly depict what occurs in the waste treatment plot. Data showing average flows are shown in table 3.

Approximately 8 c.f.s. reportedly were diverted from the drain ditch for plant use. A sewer from the plant with 1.6 c.f.s. emptied to the ditch; the main factory sewer discharged 4.3 c.f.s. to the treatment field. This leaves about 2 c.f.s. to be accounted for. In this latter figure must be included consumptive plant use, spillage to the drain ditch from the main plant sewer, by-passing to the ditch, pump station overflow to ditch, measuring error at the flume and inaccuracy in the plant diversion figure. The increase in B.O.D. at D2 was much greater than anticipated from results of D1 and S1, and indicated that waste from the main sewer line reached the drain by leakage or spillage. This was also borne out by field observation. Measuring error at the flume is quite real as the lift station pumped intermittently providing a graph difficult to total, and during quiescent conditions lime sludge had a tendency to settle in the flume.

Flow through the field during period of study was reduced from 4.3 c.f.s. to 3.5 c.f.s. or 0.8 c.f.s. (19 percent). Several factors causing this reduction are evaporation, percolation, transpiration, leakage to drain ditch, and spillage to other fields. Referring to the table on climatic data in appendix V, mean measured evaporation was 0.10 inches per day during period of study. According to the U. S. Weather Bureau, the standard evaporation pan factor is 0.7 when applied to broad water surfaces. This approximate factor is also shown in O'Rourke's General Engineering Handbook[6]. Assuming that 60 percent of the 160 acre field was wetted (see figure 5) or 96 acres, the evaporation was 0.56 acre-feet or 0.28 c.f.s. One reason for the low evaporation rate was the unusual calm weather prevailing during this study. Evaporation varies with wind velocity as shown by the following from Merriman-Wiggin's "American Civil Engineers Handbook": [5]

Wind velocity - MPH	0.0	5.0	10.0	15.0	20.0
Rel. Evaporation	1.0	2.2	3.8	4.9	5.7

The wind, measured at Bridgeport, showed a median of 1.46 miles per hour; the maximum was only 4.71. It might be anticipated that with stronger winds, evaporation would be of greater import.

Transpiration appears to be a negligible factor in water loss at this season of the year as only 6 percent of total water used by plant

consumption occurs in October and pasture growth consumption may average only 0.5 feet per year.[5]

Percolation losses on irrigated lands may vary from 20 to 75 percent of the water applied, increasing with soil porosity.[5] Soils of the North Platte valley are adaptable to irrigation and it appears reasonable to expect appreciable percolation unless extensive soil clogging occurred. Percolation could account for the major portion of the decrease in flow through the field. Yet recorded flow from October 8 to November 30 as shown in appendix V, has the average influent as 4.1 c.f.s. and effluent as 3.8 c.f.s. Recorders were installed October 7, and operated 55 days until cold weather when ice formation prompted their removal. The inflow totaled 437 acre-feet and the outflow, 343 acre-feet; the volume reduction was 21 percent. Evaporation could account for 0.28 c.f.s. until cold weather and freezing occurred. The close balance of figures would indicate clogging of soil with a minimum of percolation. Numerous prairie dogs living and burrowing over scattered parts of the treatment field indicated the ground was not saturated with water.

Occasional leakage was observed from the field to the drain ditch by overtopping and erosion of the dike or through prairie dog burrows. Laboratory data (table 3) readily substantiated this fact. The B.O.D. increased over 5,000 population equivalents from stations D2 to D3. Individual daily results are probably more significant. Generally, a downward trend was recorded between D2 and D3 showing absence of normal leakage or seepage from the field to the ditch and the effects of probable settling and natural purification proceeding in the drain ditch. However, on October 30, an 8 hour composite sample at D2 gave a B.O.D. of 41.3 ppm. while D3 showed a B.O.D. greater than 83.2 ppm.; a B.O.D. greater than 84.4 ppm. was recorded at D3 on October 27. It is apparent that the slugs of wastes reaching the ditch as breaks or leaks exert a strong influence on the drain ditch and are extremely significant. The three low recorded values for dissolved oxygen at D4 - 4.19, 4.26 and 4.22 ppm. - occurred on days when slugs caused the three highest B.O.D. results. To prevent the adverse effects of insufficiently treated wastes on the receiving water course, care must be exercised to construct and maintain dikes so as to preclude overtopping and breaks.

Spillage to other fields was only accidental and the result of equipment failure or erosion of distribution flume.

Grassland Field Sampling

Sampling of the grassland field was conducted with several objectives in view. Prime consideration was given to over-all evaluation, i.e., -- influent versus effluent samples. The second objective was to ascertain the rate of removal as the waste traversed the field by establishing quarter section sampling which would then be adjusted as necessary to locate area of maximum purification.

It was planned originally that the quarter section transect stations would be located at quarter points transversely across the field. It was quickly apparent that adhering to plan would place the western three-quarter stations generally on dry land. Accordingly, modifications were made to

locate so as to obtain representative portions of the flowing waste. Station F1350 and F1800, however, could be located at quarter points and still be in water and accordingly were established as such to show the effect of sampling from quiescent reaches of the field (figure 5). The effect of this condition becomes apparent in table 2 where B.O.D. results of these transect composites were considerably lower than subsequent downstream stations. This indicates that increasing substantially the detention time through the field may improve treatment results.

Field Maintenance and Operation

The grassland field, called by some a grassland filter and by others a settling basin, combined these two actions. Essentially, a waste with a considerable amount of suspended matter and much dissolved materials is applied to the field. Immediately, the settleable material drops from the liquid which soon becomes relatively free of suspended matter. Then, as the liquid filters through the grasses, some biological action takes place which removes a portion of soluble matter. However, it appears that biological growths did not have opportunity to demonstrate their full capabilities. The median dissolved oxygen in the effluent was zero.

There are many factors that would improve operation and treatment results of the field. The waste reaching the distribution flume contained beet tops, rootlets and other coarse matter that should be screened out at the plant. Besides preventing operational difficulties in the flume, the organic matter so recovered could be used for animal feed.

Flow from the distribution flume to the field was seldom uniform because of the intermittent operation of the lift pump and clogging of the pipes leading from the distribution canal. Rectification of these defects could readily be accomplished by a suitable pump installation and by the use of open distribution flumes leading to the field from the distribution header. This latter item was being installed during this study (figure 2).

The effectiveness of the grassland field could be improved by leveling and terracing in the manner of the border-strip method of irrigation thereby increasing the detention time through the field. Under present practice, the waste reached the field, dropped most of its suspended matter and followed three principal flow routes in the upper portion of the field that combined into one at the lower reaches. Studies showed passage of some of the waste in as short a time as 4 hours with average detention of about 14.5 hours. If leveling and terracing would permit 80 percent of the field to be usable with an average liquor depth of 3 inches, the average calculated detention time would be 72 hours or about 5 times that now occurrring. This additional time would probably permit use of a goodly portion of the field as a true biological filter with added purification particularly of the soluble fraction that is not now being removed by settling.

Field treatment appears to offer considerable flexibility. Where a lesser degree of treatment is required, a much smaller plot to provide settling only might suffice. Where land is scarce, a good deal of the solids could be prevented from reaching the grassland field by separate

disposal of filtered lime cake and the remainder of the waste treated on a smaller field.

Rapid settling of the suspended matter points towards possible consideration of conventional settling and sludge dewatering for treatment at some locations. If a high degree of treatment is essential, leveling and terracing to assure utmost detention time for maximum biological treatment may be planned.

Access to the field could be improved to aid maintenance and inspection. It would appear desirable to broaden the dike between the field and drain ditch so as to permit its use as a roadway and at the same time prevent accidental leakage from the field to the ditch. Incidentally, broadening of the dike between factory waste canal and ditch would likewise be beneficial. A roadway along the distribution flume would greatly facilitate operation and maintenance. The distribution flume should be concreted or otherwise treated to prevent erosion.

Since treatment must be considered on a long range basis, construction of facilities that will reduce operating costs is highly desirable. Calculations formulated on the settleable material in the waste and use of the upper fourth of the field for settling indicate that the treatment field could handle the settleable solids for possibly 50 years or more without serious interference with field operation.

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APPENDIXES

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LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Time	Date 1953	Avg. ° Cent.	Temp °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5 Day B.O.D. p.p.m.	Coliforms M.P.N. Per 100 ml.	37°C Stand. Plate	pH	Alkal. p.p.m.	Turb. p.p.m.	Sulfite Soln. Vol.	Sludge Total Vol.	Sludge Dissolved Vol.	Sludge Solids	Remarks
Station F1 - Influent to field (factory wastes) Composite Sample	6 a - 4 a	10/19	2				444			6.9	2,552	3,000	-	-	-	-	10 hr. composite
	6 a - 4 p	10/20	2				594			9.3	2,240	1,900	-	4,330	320	288	518	3,408	10 hr. composite
	6 a - 4 a	10/21	4				672			6.8	2,800	1,400	17.0	5,432	2,324	1,016	508	4,618	10 hr. composite
	6 a - 4 a	10/22	4				373			6.9	2,436	2,500	18.0	5,012	1,488	1,130	604	3,880	24 hr. composite
	6 a - 12n	10/26	4				746			6.0	1,167	2,600	25.0	7,362	2,758	1,140	552	6,208	8 hr. composite
	6a - 12n	10/27	4				380			8.7	1,778	1,700	13.0	6,054	1,604	1,084	504	5,086	8 hr. composite
	6 a - 12n	10/29	4				498			9.1	2,598	2,000	16.5	5,332	2,234	1,020	510	4,252	8 hr. composite
	6 a - 12n	10/30	3				298			7.4	849	800	4.0	2,448	1,052	1,030	516	1,418	8 hr. composite
	6 a - 12n	11/2	4				356			8.1	1,826	1,400	16.0	4,464	1,442	1,096	462	1,368	8 hr. composite
	6 a - 12n	11/3	6				735			9.2	4,553	1,000	28.0	8,008	3,572	1,166	650	6,842	8 hr. composite
	6 a - 4 a	11/4	5				695			6.3	2,977	2,100	18.0	6,198	1,560	1,052	540	5,144	24 hr. composite
	6 a - 12n	11/5	6				252			6.7	1,612	1,200	9.0	3,680	1,596	936	468	2,736	8 hr. composite
	6 a - 12n	11/6	6				514			8.8	3,123	2,100	19.0	7,212	2,496	1,068	562	6,184	8 hr. composite
	6 a - 4 a	11/7	5				426			6.8	2,611	2,200	16.0	5,770	2,168	1,000	476	4,770	24 hr. composite
	6 a - 12n	11/8	4				706			7.9	1,825	1,200	30.0	13,080	3,482	1,154	598	11,934	8 hr. composite
	6 a - 12n	11/10	4				714			7.7	2,236	2,900	26.0	9,784	2,448	1,176	612	8,608	8 hr. composite
Maximum			6				746			9.3	4,553	3,200	32.0	11,088	3,572	1,176	650	11,934	
Average			4.3				483			8.5	2,576	2,100	18.2	6,276	2,194	1,063	533	5,215	
Median			4				456			8.8	2,576	2,100	18.0	5,432	2,234	1,068	562	4,618	
Minimum			2				252			7.4	849	800	4.0	2,448	980	988	476	1,418	
Station F1 - Influent to field (factory wastes) Grab samples	8:15 A	10/19		25	4.80	58	208	-	-	8.9	230	340	-	-	-	-	-	-	
	10:25 A	10/20		30	1.28	19	184	2,100,000	7,000,000	8.8	1,260	2,700	-	-	-	-	-	-	
	10:45 A	10/21		28	-	-	516	-	-	8.7	2,837	1,300	-	-	-	-	-	-	
	12:45 P	10/22		36	0.46[a]	8	427	2,100,000[b]	1,300,000[b]	8.1	1,457	2,000	19.0	-	-	-	-	-	[a]Collected 11:10 A
	11:10 A	10/26		24	0.84	11	-	4,300,000	3,000,000	-	-	-	-	-	-	-	-	-	
	10:15 A	10/27		34	3.36	55	354	-	-	8.0	1,277	800	8.0	-	-	-	-	-	
	9:45 A	10/29		32	0.43	6	248	-	-	7.1	755	720	2.0	-	-	-	-	-	
	1:45 P	10/30		32	1.08[b]	17	257	1,500,000[b]	300,000[b]	8.9	1,749	2,800	23.0	-	-	-	-	-	[a]Collected 10:00 A
	10:05 A	11/2		32	0.0	0	259	9,300,000	2,770,000[b]	8.3	1,609	1,300	10.0	-	-	-	-	-	
	10:12 A	11/3		29	0.0	0	624	-	-	8.7	3,951	2,400	22.0	-	-	-	-	-	
	9:30 A	11/4		26	0.0	0	640	-	-	9.1	4,917	3,400	29.0	-	-	-	-	-	
	10:10 A	11/5		26	1.80	25	419	1,500,000	1,190,000	8.8	1,910	1,900	12.0	-	-	-	-	-	
	11:30 A	11/6		24	1.13	18	360	2,900,000[b]	10,500,000[b]	8.8	2,168	1,400	12.0	-	-	-	-	-	[a]Collected 10:00 A
	9:05 A	11/7		26	0.0	0	527	-	-	8.5	1,263	2,500	25.0	14,490	3,108	978	462	13,516	
	11:00 A	11/9		30	0.0	0	496	-	-	7.6	2,603	1,000	21.0	-	-	-	-	-	
	10:25 A	11/10		32	0.0	0	1,083	-	-	7.6	3,266	3,300	44.0	6,092	1,436	1,114	562	4,478	
Maximum				36	4.80	58	1,083	9,300,000	10,500,000	9.1	4,917	3,400	44.0	14,490	3,636	1,114	562	13,516	
Average				29	0.97	14	496	3,350,000	3,420,000	8.5	2,364	2,100	18.8	10,291	2,372	1,044	482	9,097	
Median				30	0.46	11	423	2,100,000	1,300,000	8.8	2,168	2,400	20.0	10,291	2,372	1,044	482	9,097	
Minimum				24	0	0	208	1,500,000	300,000	7.6	230	340	2.0	6,092	1,106	978	462	4,478	
Station F-300 - 300 ft. from distributing header - 8 hr. composites from 3 channels	6 a - 12n	10/30	-	-	-	-	712	2,300,000[b]	165,000[b]	7.7	4,211	3,000	30.0	7,960	1,220	1,220	610	6,740	[a]Grab from left channel
	6 a - 12n	11/2	-	-	-	-	236	-	-	7.6	836	600	2.5	3,682	732	1,076	524	606	
	6 a - 12n	11/3	-	26[b]	0.29[b]	4	444	-	-	8.1	1,676	1,200	9.5	3,396	1,176	1,284	662	2,110	[a]Grab from middle channel [b]Grab at 10:30 A
Maximum							712			8.1	4,211	3,000	30.0	7,960	1,220	1,284	662	6,740	
Average							464			7.8	2,241	1,600	14.0	4,346	1,435	1,194	599	3,152	
Median							444			7.7	1,676	1,200	9.5	3,396	1,176	1,220	600	2,110	
Minimum							236			7.6	836	600	2.5	3,682	732	1,076	524	606	
Station F-430 - 430 feet from distribution header - 8 hr. composites, 3 channels	6 a - 12n	10/26	-	-	-	-	218	230,000[b]	70,000[b]	7.6	683	110	0.2	1,120	508	1,080	462	40	[a]Grab from middle channel
	6 a - 12n	10/27	-	-	-	-	287	-	-	7.6	512	100	0.2	1,072	470	1,030	416	42	
	6 a - 12n	10/29	-	-	-	-	232	-	-	7.6	442	110	<0.1	1,296	508	1,068	438	38	
	10:30 A	11/1	-	-	-	-	-	930,000[b]	1,250,000[b]	-	-	-	-	-	-	-	-	-	[a]Grab from middle channel
	10:35 A	11/6	-	1	-	-	-	1,500,000[b]	1,350,000[b]	-	-	-	-	-	-	-	-	-	[a]Grab from middle channel
	10:15 A	11/10	-	-	-	-	380	-	-	7.7	804	800	4.5	-	-	-	-	-	
Maximum							380	1,500,000	1,350,000	7.7	804	800	4.5	1,120	508	1,080	462	42	
Average							249	887,000	890,000	7.6	561	280	1.2	1,096	491	1,059	439	37	
Median							215	930,000	1,250,000	7.5	498	110	0.2	1,096	500	1,068	438	40	
Minimum							187	230,000	70,000	7.6	442	100	<0.1	1,072	470	1,030	416	38	
Station F-400 - 400 feet from distribution header - 8 hr. composites, 3 channels	6 a - 12n	10/30	-	-	-	-	239	2,300,000[b]	48,000[b]	7.0	447	140	0.6	1,160	524	1,042	462	118	[a]Grab - middle channel
	6 a - 12n	11/2	-	-	-	-	186	-	-	7.8	542	150	0.1	1,060	462	1,088	438	32	
	6 a - 12n	11/3	-	27[b]	0.0[b]	0	261	-	-	7.5	430	140	0.2	1,272	612	1,158	534	114	[a]Grab - middle channel [b]Grab - middle channel
Maximum							261			7.8	542	140	0.4	1,272	612	1,158	534	118	
Average							229			7.4	473	140	0.3	1,164	533	1,076	475	88	
Median							239			7.5	443	140	0.2	1,160	524	1,042	462	114	
Minimum							186			7.0	430	150	0.1	1,060	462	1,088	438	32	
Station F-900 - (F-2) 900 feet from distribution header - 8 or 10 hr. composites from 3 channels	8 a - 4 p	10/20	-	-	-	-	98.8	-	-	7.9	420	65		1,060	504	918	408	132	[a]Left channel grab - Collected from distance
	11:45 A	10/21	-	30	-	-	240[b]	-	-	7.2[a]	428[b]	90[b]	-	-	-	-	-	-	
	6 a - 2 p	10/22	-	-	-	-	144	9,300,000[b]	700,000[b]	7.9	452	85	0.2	986	438	896	388	90	[a]Grab - L. channel
	6 a - 12n	10/23	-	-	-	-	197	2,300,000[b]	700,000[b]	7.7	483	70	<0.1	1,080	400	978	362	62	[a]Grab - L. channel
	6 a - 12n	10/26	-	-	-	-	131	1,500,000[b]	85,000[b]	7.9	512	70	<0.1	1,024	428	1,028	392	0	[a]Grab - middle channel
	6 a - 12n	10/27	-	-	-	-	197	-	-	7.6	514	73	0.1	936	352	984	404	-	
	6 a - 12n	10/29	-	-	-	-	218	-	-	7.6	454	90	<0.1	1,088	456	1,018	434	30	
	6 a - 12n	10/30	-	-	-	-	210	9,300,000[b]	34,000[b]	7.3	464	110	<0.1	1,064	474	976	418	88	[a]Grab - middle channel
	6 a - 12n	11/2	-	-	-	-	186	-	-	7.7	480	110	<0.1	1,052	466	1,018	434	34	
	6 a - 12n	11/3	-	30[b]	0.0[b]	0	264	-	-	7.4	434	200	0.4	1,210	578	1,130	536	80	[a]Grab - middle channel [b]Grab - middle channel
	10:30 A	11/5	-	-	-	-	-	390,000[b]	1,115,000[b]	-	-	-	-	-	-	-	-	-	[a]Grab - middle channel
	10:30 A	11/6	-	1	-	-	-	930,000[b]	1,825,000[b]	-	-	-	-	-	-	-	-	-	[b]Grab - middle channel
	6 a - 12n	11/9	-	-	-	-	286	-	-	7.3	438	230	0.1	1,200	536	1,134	518	76	
Maximum							286	9,300,000	1,825,000	7.9	514	230	0.4	1,210	578	1,130	536	132	
Average							194	3,990,000	743,000	7.6	469	110	-	1,056	480	1,007	443	80	
Median							192	1,900,000	700,000	7.6	456	80	<0.1	1,064	462	1,002	432	76	
Minimum							98.8	390,000	34,000	7.3	420	65	<0.1	936	404	896	388	30	

*Average daily flows as determined by Nebraska Department of Roads and Irrigation or U. S. Geological Survey.

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APPENDIX I - 2

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Time	Date 1953	Rec. ft	Temp °C	Dissolved Oxygen p.p.m.	% Sat.	Jtu	Coliform per 100 ml	Fec. Strep. per Plate Count	pH	Alkal. p.p.m.	Turb. p.p.m.	Chlorides p.p.m.	Nitrate Total	Nitrate Filtered	Nitrite Total	Nitrite Filtered	Remarks
F-2 left channel	6 a - 12n	11/9	-	-	-	-	297	-	-	7.5	478	230	<0.1	-	-	-	-	Sta. F-2 900 feet
Middle channel	6 a - 12n	11/9	-	-	-	-	296	-	-	7.4	485	110	<0.1	-	-	-	-	from distribution
Right channel	6 a - 12n	11/9	-	-	-	-	298	-	-	7.3	486	160	<0.1	-	-	-	-	channel
										-	-	-	-	-	-	-	-	
Station F-1350 -	6 a - 12n	10/26	-	-	-	-	119	< 30,000[a]	290,000[a]	8.0	505	50	<0.1	1,080	372	1,040	336	[a]Grab - middle channel
1350 feet from dis-	6 a - 12n	10/27	-	-	-	-	91.7	-	-	7.8	502	45	<0.1	1,038	432	1,042	348	-
irrigation header -	6 a - 12n	10/29	-	-	-	-	172	-	-	7.7	479	80	0.1	1,112	456	1,048	416	44
8 or composites	10:25 A	11/5	-	-	-	-	-	930,000[b]	490,000[b]	-	-	-	-	-	-	-	-	[b]Grab - middle channel
from 3 channels	10:30 A	11/6	-	1	-	-	-	43,000[c]	1,570,000[c]	-	-	-	-	-	-	-	-	[c]Grab - middle channel
Maximum							172	930,000	1,570,000	8.0	505	80	0.1	1,112	456	1,048	416	44
Average							138	<334,000	837,000	7.8	495	60	<0.1	1,072	414	1,050	377	32
Median							119	43,000	490,000	7.8	502	50	<0.1	1,080	412	1,042	368	32
Minimum							91.7	< 30,000	290,000	7.7	479	45	<0.1	1,038	372	1,040	336	20
Station F-1350 (F-3)	6 a - 6 p	10/29	-	-	-	-	85.0	-	-	8.0	466	60	-	1,108	360	1,000	446	102
1850 feet from dis-	9:05 A	10/31	-	10	-	-	201[d]	-	-	7.8[d]	438[d]	60[d]	-	-	-	-	-	[d]Taken from summary
irrigation header -	6 a - 2 p	11/2	-	-	-	-	93.8	930,000[e]	300,000[e]	8.0	471	70	<0.1	992	384	946	456	6 [e]Grab - left channel
8 or 10 hr. composite	6 a - 12n	11/3	-	-	-	-	110	930,000[f]	150,000[f]	7.9	461	50	<0.1	944	340	906	272	18 [f]Grab - left channel
from 3 channels	6 a - 12n	11/6	-	-	-	-	143	-	-	7.8	505	95	0.6	1,032	432	966	456	64
Maximum							162	-	150,000	8.0	505	95	0.6	1,112	456	1,000	456	102
Average							113	-	325,000	7.9	476	70	< .2	1,007	392	934	394	52
Median							102	930,000	325,000	7.8	468	65	<0.1	992	387	936	423	51
Minimum							85	-	300,000	7.8	461	50	<0.1	944	340	906	272	6
Left channel	6 a - 12n	11/6	-	7[g]	0.0[g]	0	228	-	-	7.5	518	160	0.7	-	-	-	-	- [g]Grab at 10:00 A
Middle channel	6 a - 12n	11/6	-	1[h]	1.2[h]	10	185	-	-	7.6	488	85	<0.1	-	-	-	-	- [h]Grab at 10:15 A
Right channel	6 a - 12n	11/6	-	1[i]	1.4[i]	11	87.3	-	-	8.1	534	40	<0.1	-	-	-	-	- [i]Grab at 1:10 A
Station F-2700 - (F-4)	6 a - 6 p	11/20	-	-	-	-	129	-	-	7.9	452	55	-	1,068	420	970	424	98
2700 feet from dis-	6 a - 2 p	11/22	-	-	-	-	106	9,300,000[a]	300,000[a]	7.8	443	50	<0.1	956	444	892	328	76 [a]Grab - left channel
irrigation header -	6 a - 12n	11/23	-	-	-	-	155	430,000	230,000[b]	7.9	466	50	<0.1	944	336	884	342	82 [b]Grab - left channel
8 or 10 hr. composite	6 a - 12n	11/5	-	-	-	-	197	-	-	7.8	495	85	<0.1	1,032	516	972	450	60
from 3 channels																		
Maximum							197	9,300,000	300,000	7.9	495	85	<0.1	1,068	516	972	450	98
Average							147	4,865,000	200,000	7.9	469	60	<0.1	1,038	434	936	405	79
Median							144	4,865,000	200,000	7.9	466	50	<0.1	1,030	438	931	385	79
Minimum							106	430,000	100,000	7.8	452	50	<0.1	944	336	884	328	60
Left channel	6 a - 12n	11/5	-	7[j]	1.2[j]	11	228	-	-	7.8	474	90	<0.1	-	-	-	-	- [j]Grab at 9:30 a
Middle channel	6 a - 12n	11/5	-	7[k]	1.5[k]	13	185	-	-	7.8	518	75	<0.1	-	-	-	-	- [k]Grab at 10:00 A
Right channel	6 a - 12n	11/5	-	7[l]	1.2[l]	11	141	-	-	7.8	481	75	<0.1	-	-	-	-	- [l]Grab at 10:10 A
Station F-5	6 a - 6 p	11/19	2				184			7.9	440	150	-	-	-	-	-	
Field effluent - 8,	6 a - 6 p	11/20	3				125			7.8	453	60	-	1,060	434	936	326	124
10 or 24	6 a - 2 p	11/22	3				113			7.8	458	55	<0.1	934	388	900	362	34
	6 a - 6 p	11/23	3				135			8.0	474	80	<0.1	1,032	376	838	232	204
	6 a - 12n	10/24	3				198			7.7	485	75	<0.1	1,032	428	998	352	34
	6 a - 12n	10/27	3				185			7.6	465	75	0.2	1,036	448	968	334	64
	6 a - 12n	10/29	3				176			7.9	516	55	<0.1	1,062	460	992	420	52
	6 a - 12n	10/30	3				108			7.8	432	80	0.3	878	280	872	328	6
	6 a - 12n	10/2	3				144			7.9	484	65	<0.1	982	448	922	346	80
	6 a - 12n	11/3	4				147			7.8	500	55	<0.1	1,008	428	980	424	28
	6 a - 6 a	11/4	3				144			8.0	496	75	0.2	1,078	456	940	380	138
	6 a - 12n	11/5	3				150			7.9	500	65	0.1	992	468	948	428	22
	6 a - 12n	11/6	4				132			8.0	508	65	0.1	1,018	456	964	434	52
	6 a - 6 a	11/7	5				143			8.0	463	80	0.2	910	370	828	376	82
	6 a - 12n	11/8	5				134			7.7	508	95	<0.1	1,012	426	980	468	32
	6 a - 12n	11/10	5				118			7.7	547	105	<0.1	1,080	456	1,062	49,	18
Maximum			5				216			8.0	547	150	0.3	1,080	468	1,062	498	204
Average			3.				154			7.8	484	75	-	1,005	417	941	375	63
Median			3				147			7.8	484	65	<0.1	1,032	428	966	389	50
Minimum			2				112			7.6	432	45	<0.1	878	280	838	232	6
Station F-5	8:45 A[m]	11/19	-	7	1.2	2	182	-	-	7.7	440	85	-	-	-	-	-	- [m]Rt. 3:20P, flow 2.81
Field effluent -	Hourly	11/20	-	13	0.0	0	174	11,000,000	1,200,000	7.8	416	85	-	-	-	-	-	-
from samples	9:15 A	11/21	-	9	-	-	97.4	-	-	7.6	399	55	-	-	-	-	-	-
	10:15 A	11/22	-	7	1.8	18	-	9,300,000	2,000,000	-	-	-	-	-	-	-	-	-
	10:45 C	11/23	-	9[n]	0.2[n]	3	189	230,000[o]	1,000,000[o]	7.8	471	85	<0.1	-	-	-	-	- [n]Collected at 10:45 A
	10:30 A	11/24	-	8	0.2	3	-	43,000	50,000	-	-	-	-	-	-	-	-	-
	10:35 A	11/27	-	9	0.2	4	226	-	-	7.6	499	90	<0.1	-	-	-	-	-
	10:00 A	11/29	-	12[p]	0.0[p]	0	209	-	-	7.8	490	95	<0.1	-	-	-	-	- [p]Collected at 12:30 P
	10:30 A	11/30	-	12	0.0	0	202	240,000	6,500	7.7	343	80	<0.1	-	-	-	-	-
	5:45 A	12/30	-	5	0.0	0	-	-	-	-	-	-	<0.1	-	-	-	-	-
	10:15 P	11/2	-	12	0.0	0	186	430,000	352,000	7.9	492	85	<0.1	-	-	-	-	-
	10:45 A	11/3	-	7	0.0	0	142	-	-	7.9	497	85	<0.1	-	-	-	-	- [q]Collected at 10:36 A
	4:15 A	11/4	-	5	0.0	0	180	-	-	8.0	495	95	<0.1	-	-	-	-	-
	11:30 A	11/5	-	8	1.8	9	142	150,000	250,000	8.0	503	65	<0.1	-	-	-	-	-
	11:05 A	11/6	-	8	1.89	15	138	23,000	200,000	8.0	504	65	<0.1	-	-	-	-	- [r]Collected at 10:10 A
	8:50 A	11/7	-	8	1.18	10	150	-	-	8.0	490	60	<0.1	974	426	964	410	8
	11:20 A	11/9	-	5	0.0	0	174	-	-	7.8	521	95	<0.1	-	-	-	-	-
	10:15 A	11/10	-	6	0.0	0	209	-	-	7.8	555	105	<0.1	1,078	440	1,022	440	56
Maximum			-	13	1.89	18	226	11,000,000	2,000,000	8.0	590	105	<0.1	-	-	-	-	-
Average			-	7	0.0	4	170	2,680,000	632,000	7.8	496	85	<0.1	1,026	432	934	425	32
Median			-	8	0.0	2	170	230,000	302,000	7.8	497	85	<0.1					
Minimum			-	5	0.0	0	97	43,000	6,500	7.6	399	45	<0.1	-	-	-	-	-

[a]Average daily flows as determined by Nebraska Department of Roads and Irrigation or U. S. Geological Survey.

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APPENDIX E - 9

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Time	Date 1953	Appearance	Temp. °C	Dissolved Oxygen p.p.m.	% Sat.	Turbidity	Coliform Bact. per 100 ml	Fecal Strep. Bact. per 100 ml	pH	Alkal. p.p.m.	Turb. p.p.m.	Sulfate mg/l	Hardness p.p.m.				Remarks
														Total	Ca	Mg	Non-Carb.	
Station E 1	8 a - 4 p	10/19	-	-			6.72			8.2	278	35	-					
Drain ditch - PRV	8 a - 4 p	10/20	-	-			2.35			8.2	271	30	-					
water intake - 8.10	8 a - 4 p	10/22	-	-			1.78			7.9	287	25	-					
or 24 hr. composites	6 a - 4 p	10/24	-	-			1.98			8.1	279	35	0.3					
	6 a - 12n	10/25	-	-			2.88			8.1	282	35	<0.1					
	6 a - 12n	10/27	-	-			1.89			8.0	281	35	0.1					
	6 a - 12n	10/29	-	-			2.46			8.1	279	30	<0.1					
	6 a - 12n	10/30	-	-			1.79			8.0	275	35	<0.1					
	6 a - 12n	11/2	-	-			2.16			8.2	272	35	0.15					
	6 a - 12n	11/3	-	-			1.08			8.1	314	30	<0.1					
	6 a - 4 p	11/4	-	-			5.23			8.1	274	40	0.2	716	216	666	166	70
	6 a - 12n	11/5	-	-			1.57			8.1	318	30	<0.1					
	6 a - 12n	11/6	-	-			1.39			8.0	277	30	0.1					
	6 a - 4 p	11/7	-	-			2.63			8.2	290	35	0.15					
	6 a - 12n	11/9	-	-			1.63			8.1	275	30	<0.1					
	6 a - 12n	11/10	-	-			1.53			8.0	276	30	<0.1					
Maximum							6.72			8.2	318	40	0.1					
Average							2.37			8.1	283	30	<0.1					
Median							1.98			8.1	278	30	<0.1					
Minimum							1.08			7.9	271	25	<0.1					
Grab samples	8:30 A	10/19	-	10	8.90	90	1.00	-	-	7.9	273	35	-					
	10:15 A	10/20	-	13	9.60	104	2.30	11,000,000[b]	6,000	8.1	271	35	-					[b]Omitted from averages
	10:35 A	10/21	-	10	-	-	1.28	-	-	7.9	284	25	-					
	10:50 A	10/22	-	9	10.33	108	-	430	20,000	-	-	-	-					
	1:10 P	10/23	-	10[a]	10.12[a]	103[a]	2.92	2,300[b]	20,000[b]	8.2	272	25	-					[a]Collected at 10:00 A
	10:50 A	10/26	-	10	10.70	108	4.08	-	20,000	-	-	-	-					
	10:05 A	10/27	-	10	9.87	100	1.80	210	2,400	8.0	284	25	<0.1					
	9:55 A	10/29	-	10	9.54	101	-	750	4,500	-	-	-	-					
	10:15 A	10/30	-	10	10.20	103	-	430	5,000	-	-	35	-					
	5:50 A	10/31	-	8	8.93	86	-	-	-	-	-	-	-					
	9:55 A	11/2	-	10	9.39	94	-	-	-	-	-	-	-					
	10:00 A	11/3	-	9	10.03	99	-	930	7,000	-	-	-	-					
	4:35 A	11/4	-	9	8.95	89	-	-	-	-	-	-	-					
	12:05 P	11/5	-	9	10.21	101	-	4,300	4,500	-	-	-	-					
	11:10 A	11/6	-	6	10.16	93	-	2,300	10,000	-	-	-	-					
	8:55 A	11/7	-	8	9.76	94	-	-	-	-	-	-	-					
	11:10 A	11/9	-	10	10.70	108	-	2,400	5,000	-	-	-	-					
	10:15 A	11/10	-	10	11.60	108	-	2,300	140,000	-	-	-	-					
Maximum				13	10.70	108	2.92	11,000,000[b]	140,000	8.2	284	35	-					
Average				10	9.89	99	1.90	1,640	20,200	8.0	277	30	-					
Median				10	10.03	101	1.34	2,300	6,000	8.0	273	30	-					
Minimum				6	8.90	86	1.00	210	2,500	7.9	272	25	-					
Station E 2	8 a - 4 p	10/20	-	-			37.5			8.0	245	95	-					
Drain ditch above	8 a - 2 p	10/22	-	-			49.0			7.9	343	110	-					
field. 8.10 or 24	6 a - 4 p	10/24	-	-			32.1			8.1	341	160	1.4					
hr. composites	6 a - 12n	10/30	-	-			41.3			7.9	297	100	1.2					
	6 a - 12n	11/2	-	-			44.0			8.1	288	100	1.3					
	6 a - 12n	11/3	-	-			29.2			8.1	252	80	0.8					
	6 a - 4 p	11/4	-	-			34.8			8.0	282	95	1.2					
	6 a - 12n	11/9	-	-			7.38			8.2	278	70	0.2					
	6 a - 12n	11/10	-	-			16.4			8.0	278	75	0.23					
Maximum							44.0			8.1	343	160	1.4					
Average							32.1			8.0	292	93	0.9					
Median							34.8			8.0	282	93	1.2					
Minimum							8.0			7.8	252	70	0.2					
Grab samples	1:15 P	10/23	-	13[a]	9.75[a]	105[a]	32.7	-	-	8.0	277	110	-					[a]Collected at 11:00 A
	10:00 A	10/10	-	12	9.26	98	-	"	"	"	"	"	"					
	5:45 A	10/31	-	10	8.57	87	-	-	-	-	-	-	-					
	10:00 A	11/2	-	12	8.41	89	-	"	"	"	"	"	"					
	10:10 A	11/3	-	11	9.53	99	-	-	-	-	-	-	-					
	4:10 A	11/4	-	10	8.41	85	-	"	"	"	"	"	"					
	10:10 A	11/5	-	8	9.24	93	-	-	-	-	-	-	-					
	11:45 A	11/9	-	10	10.34	104	-	230,000	174,000	-	-	-	-					
	10:20 A	11/10	-	10	10.39	105	-	230,000	175,000	-	-	-	-					
Maximum				13	10.39	106		230,000	175,000									
Average				11	9.31	96		230,000	174,000									
Median				10	9.26	98		230,000	174,000									
Minimum				9	8.41	84		230,000	174,000									
Station E-3	8 a - 4 p	10/20	-	-			28.7			8.0	277	85	-	-	-	-	-	-
Upstream from field	8 a - 2 p	10/22	-	-			34.0			8.0	138	110	-	-	-	-	-	-
effluent. 8.10 or	6 a - 4 p	10/24	-	-			21.2			8.0	287	80	0.7	810	226	710	248	100
24 hr. composites	6 a - 12n	10/26	-	-			33.8			8.0	290	80	0.9	-	-	-	-	-
	6 a - 12n	10/27	-	-			24.4			7.7	317	100	0.8	-	-	-	-	-
	6 a - 12n	10/29	-	-			46.2			8.0	299	100	1.4	-	-	-	-	-
	6 a - 12n	10/30	-	-			241.2			7.7	400	85	0.6	-	-	-	-	-
	6 a - 12n	11/2	-	-			39.4			7.9	284	85	1.0	-	-	-	-	-
	6 a - 12n	11/3	-	-			23.7			8.0	281	80	0.7	-	-	-	-	-
	6 a - 4 p	11/4	-	-			29.1			7.9	280	90	0.8	758	218	680	218	78
	6 a - 12n	11/5	-	-			19.0			8.1	307	85	0.7	750	272	692	216	98
	6 a - 12n	11/6	-	-			57.1			8.0	328	90	0.5	810	286	750	274	60
	6 a - 4 p	11/7	-	-			29.6			8.1	286	75	0.6	-	-	-	-	-
	6 a - 12n	11/9	-	-			12.0			8.1	284	65	0.2	764	182	640	186	134
	6 a - 12n	11/10	-	-			11.2			8.0	284	70	0.3	-	-	-	-	-
Maximum							241.2			8.1	400	110	1.4	810	286	750	274	134
Average							137.1			8.0	304	85	0.7	786	237	694	228	92
Median							30.0			8.0	287	85	0.7	780	226	692	248	98
Minimum							11.2			7.7	277	65	0.2	758	182	640	186	60

[a]Average daily flows as determined by Nebraska Department of Roads and Irrigation or U. S. Geological Survey.

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APPENDIX I - A

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Time	Date 1953	Amt. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	Chlorides p.p.m.	Total Coliform Agar Plate Count	pH	Alkal. p.p.m.	Turb. p.p.m.	Sol. Solids M/l	BOD Total	BOD 5 Day	P.V.M. Dissolved	P.V.M. Sus-pended	Remarks
Station B-1 (Contd.)	8:30 A	10/19	-	12	7.60	78	35.9	-	-	7.8	276	95					
Upstream from field effluent	10:40 A	10/22	-	12	8.91	90	-	-	-	-	-	-					
Grab samples	1:30 P	10/23	-	12	8.45[a]	87[a]	77.8	-	-	7.8	348	85					[a] Collected at 10:45 A
	10:30 A	10/26	-	12	7.58	80	-	-	230,000	-	-	-					
	10:35 A	10/27	-	12	7.44	79	-	2,400,000	150,000	-	-	-					[a] Collected at 10:40 A
	12:25 P	10/28	-	18	6.97	84	-	750,000[a]	81,000[a]	-	-	-					
	10:40 A	10/30	-	13	7.04	79	-	930,000	115,000	-	-	-					
	5:35 A	10/31	-	10	8.69	88	-	-	-	-	-	-					
	12:20 P	11/2	-	14	7.18	80	-	-	-	-	-	-					
	10:30 A	11/3	-	11	7.70	80	-	190,000[a]	1,900,000[a]	-	-	-					[a] Collected at 11:35 A
	7:15 A	11/4	-	9	8.46	84	-	-	-	-	-	-					
	10:50 A	11/5	-	8	7.87	78	-	43,000[a]	210,000[a]	-	-	-					[a] Collected at 10:55 A
	11:50 A	11/6	-	7	8.04	80	-	93,000[a]	210,000[a]	-	-	-					
	8:45 A	11/7	-	9	8.04	85	-	-	-	-	-	-					
	10:20 A	11/9	-	10	9.33	95	-	430,000	1,600,000	-	-	-					
	10:35 A	11/10	-	8	9.70	94	-	230,000	387,000	-	-	-					
Maximum				18	9.70	95	77.8	2,400,000	1,900,000	-	348	95					
Average				11	7.96	82	51.8	458,000	522,000	-	312	90					
Median				10	8.28	83	56.8	590,000	210,000	7.8	312	90					
Minimum				7	6.69	78	35.9	43,000	81,000	-	276	85					
Station D-4	S a - 4 A	10/20	40	-			38.4			7.8	283	100	-	-	-	-	-	-
1320 feet downstream	S a - 2 A	10/22	39	-			55.4			8.0	375	130	-	-	-	-	-	-
from field effluent	S a - 4 A	10/26	38	-			54.6			8.0	315	90	0.1	816	232	196	168	43
6, 10, or 24 hr.	S a - 12n	1/26	37	-			52.8			7.9	315	85	0.8	-	-	-	-	-
composites	S a - 12n	10/27	36	-			51.4			7.7	327	100	1.3	-	-	-	-	-
	S a - 12n	10/29	37	-			47.5			7.9	343	140	4.5	-	-	-	-	-
	S a - 12n	10/30	37	-			47.4			7.8	326	110	4.2	-	-	-	-	-
	S a - 12n	11/2	36	-			72.0			7.6	329	95	0.9	-	-	-	-	-
	S a - 12n	11/3	36	-			42.4			7.9	309	70	0.7	-	-	-	-	-
	S a - 4 A	11/4	36	-			57.6			7.8	359	110	0.9	888	248	720	480	168
	S a - 12n	11/5	36	-			32.8			8.1	310	75	0.7	784	224	616	216	90
	S a - 12n	11/6	36	-			46.0			8.0	330	70	0.8	792	224	616	224	168
	S a - 4 A	11/7	38	-			54.2			8.1	335	85	1.0	-	-	-	-	-
	S a - 12n	11/9	36	-			45.2			7.8	319	75	0.6	732	144	648	120	48
	S a - 12n	11/10	36	-			40.8			7.8	322	80	0.7	-	-	-	-	-
Maximum			40				57.6			8.1	375	140	1.3	888	248	720	240	210
Average			37.0				52.4			7.9	324	93	0.8	804	228	634	187	144
Median			36				52.6			7.9	319	90	0.8	792	224	634	204	168
Minimum			36				32.8			7.7	283	65	0.1	732	144	384	120	48
Grab samples	9:00 A	10/19		13	5.88	64	42.6	-	-	7.8	291	100					
	10:50 A	10/20	-	-	-	-	-	2,100,000	800,000	-	-	-					
	10:40 A	10/22		9	6.80	67	-	930,000	700,000	-		-					
	1:25 P	10/23	-	10[a]	6.35[a]	64	32.2	930,000[a]	230,000[a]	8.0	280	80					[a] Collected at 10:30 A
	10:15 A	10/26	-	10	6.38	65	-	930,000	158,000	-	-	-					
	11:00 A	10/27	-	12	5.33	56	-	930,000	93,000	-	-	-					
	12:50 P	10/29	-	16	4.19	48	-	230,000[a]	158,000[a]	-	-	-					[a] Collected at 10:20 A
	10:50 A	10/30	-	14	4.25	47		930,000	214,000			-					
	5:05 A	10/31	-	9	5.28	52		-	-			-					
	10:3_ A	11/2	-	12	4.32	46		-	-			-					
	10:55 A	11/3	-	11	5.47	57		430,000	1,660,000			-					
	3:55 A	11/4	-	8	4.49	43		-	-			-					
	11:20 A	11/5	-	7	5.89	56		93,000	370,000			-					
	10:40 A	11/6	-	6	6.96	64		150,000	400,000			-					
	8:28 A	11/7	-	8	6.11	59		-	-			-					
	10:30 A	11/9	-	8	6.81	66		930,000	1,900,000			-					
	2:30 A	11/10	-	8	7.34	71		230,000	320,000			-					
Maximum				16	7.34	71	42.6	2,100,000	1,900,000	8.0	291	100					
Average				10	5.74	58	34.4	734,000	615,000	7.9	286	90					
Median				10	5.88	58	34.4	930,000	460,000	7.9	286	90					
Minimum				6	4.19	43	29.2	93,000	93,000	7.8	280	80					
Station B-1	L 6:15 A	10/46	1,180	7	5.46	53	14.9	-	-	8.0	377	95					
McCrew Bridge - 5	R 6:00 A			7	4.69	43		-	-								
miles upstream from	L 9:45 A	10/27	1,160	9	6.30	60	12.4	240,000	730,000	7.8	376	79					
drain ditch (left &	R 9:50 A			9	5.81	58		150,000	185,000								
right channel)	L 10:45 A	10/29	1,150	10	4.56	44	17.4	430,000	145,000	7.9	344	85					
	R 10:50 A			10	3.74	38		230,000	150,000								
	L 9:30 A	11/30	1,150	10	4.36	42	11.7	-	-	7.8	353	65					
	R 9:40 A			10	3.49	35		-	-								
	L 6:30 A	10/31	1,150	10	5.79	58	18.9	-	-	8.0	360	70					
	R 6:35 A			10	3.33	34		-	-								
	L 9:25 A	11/2	1,140	10	4.30	44	12.8	210,000	275,000	8.0	362	65					
	R 9:30 A			10	3.61	39		93,000	1,280,000								
	L 9:35 A	11/3	1,120	9	3.26	32	25.7	430,000	240,000	8.0	410	110					
	R 9:45 A			9	3.10	33		430,000	580,000								
	L 6:30 A	11/4	1,110	8	3.58	35	21.0	-	-	8.1	382	140					
	R 6:35 A			8	4.33	42		-	-								
Maximum				10	5.60	53		430,000	700,000								
Average				9	4.03	40		278,000	340,000								
Median	Left			10	4.08	42		240,000	258,000								
Minimum				7	2.79	28		210,000	145,000								
Maximum				10	4.60	43		430,000	1,280,000								
Average	Right			9	3.66	36		226,000	549,000								
Median				10	3.78	36		190,000	382,000								
Minimum				7	3.10	33		93,000	150,000								
Maximum			1,180	10	5.60	53	25.7	430,000	1,280,000	8.1	410	140					
Average	Combined		1,140	9	3.84	38	16.8	252,000	444,000	8.0	370	93					
Median			1,150	10	3.78	40	16.2	230,000	258,000	8.0	369	90					
Minimum			1,110	7	2.79	28	11.7	93,000	145,000	7.8	344	65					

*Average daily flows as determined by Nebraska Department of Roads and Irrigation or U. S. Geological Survey.

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APPENDIX I - 5

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Time	Date 1970	Flow - CFS	Temp °C	Dissolved Oxygen P.P.M.	%	BOD 5 day P.P.M.	COD P.P.M.	TOC Total Org. Carbon	pH	Alkal. P.P.M.	Turb. J.T.U.	Fecal Coliform MPN/100 ml	Fecal Strep. MPN/100 ml	Total Coliform MPN/100 ml	Remarks
Station 8+1	11:00 A	10/30	1,240	11	5.71	61	15.7	-	-	6.6	181	200				
1/2 mile upstream	9:30 A	10/31	1,230	11	-	-	11.6	-	-	7.9	137	95				
Cows drain ditch	9:45 A	10/31	1,220	7	6.21	58	11.9	-	-	6.0	188	100				
Leisure Acres - Pond	7:00 A	11/1	1,190	7	4.93	47	17.6	-	-	6.1	184	180				
Farmers Pond	11:35 A	11/1	1,190	6	4.91	57	16.6	-	-	6.0	158	180				
	10:10 A	11/2	1,190	4	4.93	41	14.1	-	-	6.1	208	150				
	8:15 A	11/7	1,190	3	5.82	52	17.7	-	-	6.2	166	120				
	10:15 A	11/9	1,130	8	5.85	57	14.1	230,000	500,000	6.0	180	95				
	11:08 A	11/10	1,110	7	5.91	56	14.4	9,300	431,000	7.9	211	60				
Maximum			1,240	11	6.21	61	17.8	230,000	500,000	6.6	208	180				
Minimum			1,110	3	4.91	41	11.9	9,300	230,000	6.0	158	60				
Median			1,190	7	5.88	57	14.4	119,650	428,000	6.0	180	120				
Maximum			1,110	4	4.93	47	11.6	9,300	431,000	7.9	211	60				
Station 8+4	A 1:05 P	11/10	1,140	16	4.65	44	18.0	-	-	8.1	184	70				
Union Pacific RR	C 1:10 P			16	4.82	45		-	-							
Bridge (2-1/2 mile	B 1:14 P			16	5.34	48		-	-							
downstream; left bank	A 11:05 A	10/27	1,240	10	4.98	42	11.6	93,000	295,000	7.0	270	90				
mixed left, center, A	C 11:30 A			10	5.58	52		460,000	743,000							
right channels	B 11:35 A			10	5.79	59		75,000	230,000							
	10: 10:10 A	10/29	1,210	12	4.30	42	16.0	230,000	383,000	7.8	158	95				
	BL 10:15 A			12	4.78	44		230,000	330,000							
	C 10:20 A			12	4.99	53		43,000	150,000							
	B 10:25 A			12	4.68	50		93,000	430,000							
	9: 9:45 A	10/30	1,230	11	4.62	47	14.7	-	-	7.8	172	80				
	BL 9:50 A			11	5.02	52		-	-							
	C 9:55 A			11	5.17	53		-	-							
	B 10:00 A			11	5.16	53		-	-							
	7: 7:05 A	10/31	1,230	12	4.60	43	17.3	-	-	6.1	144	85				
	BL 6:55 A			12	5.18	55		-	-							
	C 6:50 A			12	5.07	58		-	-							
	B 6:45 A			12	5.51	58		-	-							
	11: 11:40 A	11/3	1,220	11	4.42	40	10.3	430,000	460,000	8.0	159	63				
	BL 11:45 A			10	5.18	52		93,000	430,000							
	C 11:50 A			10	5.80	53		93,000	150,000							
	B 11:55 A			10	5.48	52		430,000	150,000							
	10: 11:53 A	11/3	1,210	10	4.49	40	14.9	93,000	280,000	8.0	145	80				
	BL 11:57 A			10	5.15	54		93,000	431,000							
	C 12:02 A			10	5.86	57		930,000	431,000							
	B 12:05 A			10	5.79	59		93,000	380,000							
	11: 7:55 A	11/4	1,200	7	4.94	44	18.6	-	-	7.9	160	110				
	BL 7:50 A			7	5.34	48		-	-							
	C 7:45 A			7	5.38	48		-	-							
	B 7:39 A			7	5.12	48		-	-							
	10: 11:55 A	11/5	1,200	8	6.23	56	11.6	-	-	8.0	170	85				
	BL 12:00 A			8	6.51	58		-	-							
	C 12:05 A			8	6.39	59		-	-							
	B 12:10 A			8	5.73	54		-	-							
	10: 7:45 A	11/7	1,200	5	4.39	37	17.2	-	-	7.2	160	120				
	BL 7:40 A			5	5.68	46		-	-							
	C 7:32 A			4	5.67	38		-	-							
	B 7:30 A			4	5.82	41		-	-							
	12: 9:30 A	11/9	1,180	8	5.66	55	15.4	93,000	430,000	8.0	173	93				
	BL 9:45 A			8	5.81	56		93,000	430,000							
	C 9:40 A			8	5.85	57		230,000	580,000							
	B 9:35 A			7	6.03	57		75,000	400,000							
	12: 9:45 A	11/10	1,160	7	5.34	48	14.9	230,000	226,000	7.8	160	80				
	BL 9:40 A			7	5.50	50		43,000	210,000							
	C 9:35 A			7	5.59	53		430,000	460,000							
	B 9:30 A			6	5.56	52		230,000	240,000							
Maximum				16	6.39	57		430,000	430,000							
Average Left				10	4.90	48		161,000	377,000							
Median Left				10	4.84	50		162,000	285,000							
Minimum				3	3.66	48		93,000	220,000							
Maximum				12	6.68	60		230,000	455,000							
Average Right				9	5.52	54		230,000	321,000							
Median Left				9	5.47	53		93,000	400,000							
Minimum				5	4.78	48		43,000	170,000							
Maximum				16	6.47	59		930,000	520,000							
Average Center				9	5.54	55		384,000	318,000							
Median				10	5.50	54		330,000	198,000							
Minimum				4	4.85	48		43,000	150,000							
Maximum				16	6.58	62		430,000	560,000							
Average Right				9	5.65	56		166,000	318,000							
Median				10	5.54	58		93,000	285,000							
Minimum				4	4.85	48		75,000	150,000							
Maximum			1,230	16	6.98	68	17.1	930,000	560,000	8.0	185	180				
Average Comp.			1,220	9	5.39	53	13.1	212,000	334,000	8.0	160	90				
Median blend			1,220	10	5.29	54	14.1	93,000	308,000	8.0	166	85				
Minimum			1,140	4	3.65	48	10.3	43,000	150,000	7.8	134	60				
Station 8+4 Below	B 11:25 A	10/28	1,210	13	5.61	61	11.6			8.0	174	90				
Diversion Dam (2-1/2	7:05 A	10/24	1,270	7	7.30	68	9.98			8.1	147	65				
miles downstream from																
Cows drain)																
Average			1,240	10	6.46	65	10.7			8.0	132	90				
Station 8+4 NR Below	9:50 A	10/30	1,240 E	11	-	-	8.96			7.9	Inc.	65				Flows estimated
Above Brainerd (12	9:30 A	11/6	1,200 E	3	5.17	78	14.8			8.1	138	110				" "
miles downstream from																
Cows drain)																
Average			1,240	7	5.17	78	11.8			8.0	151	108				
Station 8+1 Primary	A a - 8 a	10/28	1.8				335			7.3	299	900	18.0			
Outlet from secondary	A a - 8 a	10/24	"				388			6.7	321	1,000	18.0	8.10k	1.10k	1.0k6	60k	1.0k6
12" sewer (downstream	A a - 12k	10/28	1.4				361			6.7	332	1,000	9.0			
to Station 9+ from below																
Dell) (Composite)																
Average			1.4				377			6.9	324	1,000	18.0			
Cows drainage	11:00 A	10/26	-	17	2.81	34	-	230,000	1,700,000							
	1:10 P	10/27	1.4	16[a]	0.80[a]	10[a]	510	9,300,000[a]	8,000,000[a]	7.0	244	1,000	18.0			[a]Collected at 10:10 A
	11:10 A	11/9	-	-	-	-	-	1,500,000	1,000,000							
	10:10 A	11/10	-	20	2.18	29	-	240,000,000	240,000,000							
Average				14	1.99	20		1,400,000*	1,900,000*							*Median

*Average daily flows as determined by Nebraska Department of Roads and Irrigation or U. S. Geological Survey.

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APPENDIX II

Analyses Conducted at Lincoln and as reported by the Division of Laboratories, Department of Health, State of Nebraska

Station	Sample Collected Date 1953	Time	Date Anal. Begun in Laboratory[d]	Water Temp. in Field	C pH	Total Alk. ppm	Hardness ppm	Total Solids ppm	Ash ppm.	Dissolved Solids ppm	Ash ppm.	Fe ppm	Mn ppm	Cl^- ppm	$SO_4^=$ ppm	K ppm	Na ppm	Ca ppm	Mg ppm
F - 1	10-22	12:30 p	10-26	34	7.1	482[b]	656[b]	5,716	1,750	1,056	308	-	1.0[a]	20.9	169[b]	47	52	138[b]	72[b]
F - 1	10-30	2:25 p	10-31	32	7.3	1008[b]	650[b]	19,530	2,790	1,174	302	0.4	5.1[a]	22.8	127[b]	41	59	121[b]	84[b]
F - 1	11-15	3:45 p	11-17	-	-	524[b]	678[b]	7,192	1,382	1,318	450	-	2.1[a]	21.8	171[b]	60	77	143[b]	78[b]
F - 5	10-22	10:40 a	10-26	7	7.5	438	422	908	252	760	184	-	0.2	29.4	143	49	67	70	58
F - 5	10-30	2:00 p	10-31	15	7.3	540	484	990	296	874	218	0.3	0.12	28.5	136	60	68	81	64
F - 5	11-15	3:35 p	11-17	-	-	630[b]	560[b]	1,270	482	1,192	414	-	0.22	25.6	102[b]	60	84	108[b]	69[b]
D - 1	10-22	11:00 a	10-26	9	7.7	268	306	664	150	644	144	-	0.025	20.9	180	22	55	62	39
D - 1	10-30	2:15 p	10-31	13	8.1	240	329	660	140	618	118	0.2	0.03	21.8	184	22	52	71	35
D - 3	11-15	3:35 p	11-17	-	-	282[b]	276[b]	812	118	694	116	-	0.15	20.9	175[b]	16	82	56[b]	32[b]
D - 4	10-22	10:30 a	10-26	9	7.5	306	368	776	138	660	124	-	0.03	20.9	173	24	55	64	49
D - 4	10-30	1:50 p	10-31	15	7.3	346	352	810	120	686	118	0.25	0.08	23.7	160	27	54	66	42
D - 4	11-15	3:15 p	11-17	-	-	354[b]	344[b]	914	164	742	158	-	0.22	21.8	168[b]	23	82	67[b]	42[b]

Note:

F-1 Factory waste
F-5 Field effluent
D-1 Ditch, factory water intake
D-3 Ditch, upstream from field discharge
D-4 Ditch, 1/2 mile below field discharge

a. With mud
b. Results on filtered samples
c. pH determined in laboratory
d. Samples iced during transportation

APPENDIX III - Analyses Conducted by Great Eastern Sewer Company - 1971

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Type	Date 1971	Sus. Sol.	Temp. °C	Dissolved Oxygen		Coliform	Fecal Coliform	pH	Turb. p.p.m.	Solids				Remarks
											Total	Dissolved	Suspended Vol.	Fix.	
Sta. P-1															
Main Factory Sewer	Grab	10/21		20	-				9.30		7,536	3,388	1,376	6,160	Collected at 10:15 A
	8 hr.Composite	11/4		24	0.71				9.05		13,008	1,490	1,084	11,944	
	Grab	12/3		-	1.03				9.05		5,368	1,678	1,120	4,288	
	Grab	12/18		-	0.0				9.40		12,494	2,434	1,356	11,138	
Maximum									9.40		13,008	3,616	1,376	11,944	
Average									9.20		9,663	1,770	1,204	8,663	
Median									9.18		10,115	2,033	1,193	8,774	
Minimum									9.05		5,368	1,490	1,056	4,288	
Sta. P-2															
1/4 Sectional Sample	Grab	10/21		10	-				7.40		1,044	414	1,022	42	
Sta. P-3															
1/2 Sectional Sample	Grab	10/21		10	-				7.65		962	368	918	44	
Sta. P-4															
Field effluent	Grab	10/21		9	-		143		7.90		904	334	868	36	
	8 hr.Composite	11/4		1	0.58		154		8.05		962	440	962	0	
	Grab	12/3		-	0.0		320		7.70		1,144	540	1,140	4	
	Grab	12/18		-	0.0		478		6.90		1,269	518	1,298	4	
Maximum							478		8.05		1,269	640	1,098	34	
Average							284		7.66		1,075	506	1,070	11	
Median							232		7.80		1,063	529	1,063	4	
Minimum							143		6.90		904	334	868	0	
Sta. P-1	Grab	10/21		10	-		4		8.60		700	130	674	26	
Drain ditch - Water	8 hr.Composite	11/4		6	9.47		2		8.40		728	588	672	56	
Sample	Grab	12/3		-	10.5		1		8.25		660	106	576	84	
	Grab	12/18		-	10.8		2		8.20		684	98	644	40	
Maximum							4		8.60		728	588	674	84	
Average							3		8.36		688	230	662	66	
Median							2		8.32		706	118	658	68	
Minimum							2		8.20		660	98	576	26	
Sta. P-4	8 hr.Composite	11/4		4	4.22		58		8.25		782	604	764	36	
Ditch below field	Grab	12/3		-	4.85		181		8.70		1,954	608	796	1,158	
effluent	Grab	12/18		-	6.73		73		7.80		928	180	738	190	
Maximum							181		8.70		1,954	608	796	1,158	
Average							108		8.05		1,221	464	760	461	
Median							73		8.25		928	604	764	190	
Minimum							58		7.80		782	180	738	36	
Sta. P-2	Grab - Sc.bank	10/21		11	-		16		8.60		918	144	684	234	
River above Factory	Grab - Sc.bank	11/4		3	-		10		8.35		1,368	1,154	806	562	
outlet	Grab - Sc.bank	12/3		-	.49		30		8.10		908	264	616	286	
	Grab - Sc.bank	12/18		-	5.46		32		8.10		1,008	158	642	366	
Maximum							32		8.60		1,368	1,154	806	562	
Average							22		8.34		1,049	635	692	356	
Median							23		8.22		963	214	673	324	
Minimum							10		8.10		908	158	632	234	
Sta. P-4	Grab -SR bridge	10/21		11	-		11		8.60		904	160	674	234	
River at Bridgeport	Grab -SR bridge	11/4		3	8.48		11		8.35		1,408	1,160	700	900	
	Grab -SR bridge	12/3		-	7.38		25		8.10		892	264	654	260	
	Grab -SR bridge	12/18		-	8.34		29		8.10		1,160	178	682	478	
Maximum							29		8.60		1,408	1,160	700	900	
Average							20		8.34		1,154	534	678	458	
Median							19		8.22		1,277	212	680	369	
Minimum							11		8.10		892	160	654	234	

Note:

1. (Sta. 4 and Sta. 1 - ... Ratio of ... river at ... Point.
2. All ... grab ... taken ... waters at ... ebb.
3. Sta. 3 - ... aeration field by-passed; P-3 ... at 1/8 ... flow.

APPENDIX IV

Results of Flow Study Using Dyes

Location of Dye*	Time of Observation	Remarks
Preliminary Study Nov. 11, 1953 using fluorescein		
Dye introduced - plant manhole	1:35 P	To determine flow time from plant to west end of flume
Pump (F-1)	1:48 P	
West end of flume	2:04 P	
November 12, 1953 using Congo Red		
Dye introduced - plant manhole	8:00 A	
Outlet to open channel	8:10 A	
Pump	8:15 A	
Field channels		Dye faded out in all three principal channels within 500 feet of distribution flume
Nov. 12, 1953 using fluorescein		
East Channel (left channel looking downstream)		
Dye leaves flume	9:22 A	
S 300 - W 100	9:30 A	
S 500 - W 100	9:35 A	Spreading in pool
S 700 - W 20	10:00 A	Good diffusion in pool
S 800 - W 100	10:20 A	In pool, bearing towards right side of pool
S 900 - W 10	10:50 A	Leaving pool
S 1100 - W 10	11:00 A	In channel along dike
S 1300 - W 10	11:15 A	In channel along dike
S 1500 - W 150	11:30 A	Fast current in SW direction entering algae-laden area
-	-	Color indistinguishable from algae
Middle Channel		
Dye leaves flume	9:25 A	
S 300 - W 700	9:31 A	
S 500 - W 400	9:40 A	Entering middle pool
S 525 - W 600	10:06 A	
S 700 - W 380	10:40 A	In pool, well spread out
S 800 - W 380	10:50 A	In pool, well spread out
S 925 - W 375	11:25 A	
-	-	Lost in algae waters
West Channel (right channel looking downstream)		
Dye leaves flume	9:32 A	About 1125 ft. west along flume header
S 280 - W 950	9:40 A	
S 280 - W 1020	9:40 A	
S 350 - W 1000	9:40 A	Running into still pool
S 450 - W 1000	10:03 A	Flowing from pond into grass area
S 460 - W 960	10:14 A	
S 475 - W 1000	10:15 A	
S 500 - W 975	10:20	Flow S and SW toward S 500 - W 1000
S 500 - W 900	10:23 A	Flow SW
S 490 - W 1010	10:25 A	Flow SW
S 275 - W 1300	10:30 A	In pool
S 375 - W 1075	10:35 A	Flow W
S 520 - W 1000	10:40 A	Flow S
S 625 - W 800	10:40 A	Flow SE
S 650 - W 1050	11:00 A	Flow S in pool
S 675 - W 800	11:05 A	Flow S in grass
S 700 - W 725	11:10 A	Flow SE in grass
S 700 - W 1075	11:15 A	Flow S in pool
S 300 - W 1300	11:20 A	In pool
S 500 - W 1300	11:20 A	In pool, flow S, grass bottom
S 775 - W 675	11:30 A	Flow SE, difficult to find
S 900 - W 725	11:50 A	In channel, flow S SW turn off to SE
S 975 - W 750	11:55 A	In channel, flow S SW turn off to SE
S 775 - W 1075	12:00 A	In pool, no apparent outflow
S 725 - W 1175	12:00 A	In pool, no apparent outflow
S 700 - W 925	12:00 P	Flows from ditch, in grass
S 1030 - W 1230	2:40 P	In swamp between dams
S 1200 - W 1000	2:45 P	Flowing SW into pool
S 1885 - W 415	3:00 P	Strong flow and green color
-	-	Dye lost

* S - South
W - West
Distance in Feet

Results of Flow Study Using Salt (Sodium Chloride)

1000 pounds feed salt added to waste pump intake 12:40 p.m. on November 13, 1953.

Date	Hour	Chloride Concentration
Station F-1		
11-13-53	12:05 P	24.7
	12:55 P	344.
	1:05 P	340.
Station F-5		
11-13-53	12:00 noon	12.6
	1:00 P	14.7
	2:00 P	11.9
	3:00 P	16.5
	4:00 P	20.6
	5:00 P	27.0
	6:00 P	17.6
	7:00 P	12.1
	8:00 P	17.2
	9:00 P	13.8
	10:00 P	16.9
	11:00 P	14.7
	12:00 Midnight	16.1
11-14-53	1:00 A	22.3
	2:00 A	24.4
	3:00 A	34.6
	4:00 A	19.5
	5:00 A	18.8
	6:00 A	13.3
	7:00 A	11.9
	8:00 A	12.5
	9:00 A	10.4
	10:00 A	15.5
	11:00 A	13.9
	12:00 noon	21.0
	1:00 P	10.6
	2:00 P	14.7
	3:00 P	14.4
	4:00 P	13.3
	5:00 P	17.5
	6:00 P	11.9
	7:00 P	11.3
	8:00 P	12.6
	9:00 P	12.6
	10:00 P	11.9
	11:00 P	11.9
	12:00 Midnight	12.6
11-15-53	1:00 A	13.3
	2:00 A	11.9
	3:00 A	9.2
	4:00 A	10.6
	5:00 A	11.9
	6:00 A	9.2
	7:00 A	10.6
	8:00 A	11.9
	9:00 A	11.9
	10:00 A	11.9
	11:00 A	11.3
	12:00 noon	12.6
	1:00 P	11.9
	2:00 P	11.9

APPENDIX V

Climatic Conditions and Inflow and Outflow of Treatment Field

Date 1953	Treatment Field Inflow c.f.s.	Treatment Field Outflow c.f.s.	Havard Temperature Max.	Havard Temperature Min.	Havard Temperature 5 p.m.	Havard Evaporation inches	Havard Precipitation inches	Bridgeport Evaporation inches	Bridgeport Precipitation inches	Bridgeport Wind Velocity MPH
Oct. 8(b)	1(a)	0(a)	-	-	-	-	-	.17	0	1.04
9	2	0	-	-	-	-	-	.07	0	0.79
10	4	0	-	-	-	-	-	.25	0	0.67
11	5	0	84	37	69	-	0	.27	0	2.00
12	4	0	84	39	71	-	0	.16	0	2.54
13	2	0	76	41	65	-	0	.20	0	1.21
14	4	0	74	35	65	-	0	.05	0	1.67
15	4	0	74	38	67	-	0	.25	0	2.12
16	3	2	72	40	60	-	.03	.21	.04	2.71
17	2	1	76	32	60	.16	0	.13	0	1.29
18	2	0	80	30	67	.15	0	.15	0	1.04
19	2	2	78	38	67	.18	0	.13	0	0.79
20	2	3	74	38	57	.04	.15	.11	.19	1.00
21	2	3	69	43	48	.13	12	.08	.34	3.12
22	4	3	51	31	46	.12	0	•	0	4.71
23	5	3	46	26	43	.03	0	•	0	1.29
24	5	3	49	38	43	.04	.02	.22	.07	2.21
25	2	3	50	32	40	.12	0	•	0	2.58
26	4	3	57	21	49	.05	0	•	0	0.42
27	4	3	63	35	58	.14	0	.20	0	2.62
28	4	3	71	34	56	.11	0	.10	0	1.62
29	4	3	76	25	53	.13	0	.11	0	1.08
30	3	3	64	29	55	.10	0	•	0	1.62
31	4	4	64	25	54	.09	0	.08	0	0.54
Nov. 1	4	3	72	27	62	.10	0	.11	0	1.04
2	4	3	70	46	49	.24	0	.21	0	1.25
3	6	4	50	39	41	.11	0	.11	0	1.79
4	5	3	42	34	37	.07	0	.08	0	1.58
5	6	3	39	34	35	.03	0	.04	0	3.08
6	6	4	35	30	30	.01	0	-	.06	4.25
7	5	5	51	29	42	-	.11	-	0	3.71
8	5	4	56	17	43	-	0	.02	0	0.54
9	4	5	67	18	40	-	0	.05	0	1.33
10	4	5	57	21	45	-	0	.02	0	0.38
11	4	4	57	23	43	-	0	.02	0	1.04
12	3	4	71	22	57	-	0	.04	0	1.17
13	5	5	73	26	54	-	0	.05	0	0.50
14	6	5	78	26	69	-	0	.06	0	0.46
15	6	5	71	26	53	-	0	.09	0	1.54
16	6	6	71	25	50	-	0	•	0	0.08
17	2	5	74	24	48	-	0	•	0	0.88
18	0	1	51	29	29	-	0	.21	0	2.92
19	0	1	29	13	22	-	.08	-	.19	-
20	0	1	31	12	26	-	0	-	0	-
21	6	3	29	10	24	-	0	-	0	-
22	2	8	46	9	41	-	0	-	0	-
23	4	2	48	38	39	-	0	-	0	-
24	6	5	49	20	40	-	0	-	0	-
25	7	7	53	24	42	-	0	-	0	-
26	5	6	53	24	43	-	0	-	0	-
27	6	6	54	24	44	-	0	-	0	-
28	7	6	48	30	37	-	0	-	0	-
29	8	6	56	18	42	-	0	-	0	-
30	8(d)	6(d)	58	17	43	-	0	-	0	-
Dec. 1	-	-	50	24	33	-	0	-	0	-
2	-	-	41	19	33	-	0	-	0	-
3	-	-	33	26	26	-	0	-	0	-
4	-	-	34	21	25	-	0	-	0	-
5	-	-	24	9	26	-	0.12	-	T	-
6	-	-	18	11	40	-	0	-	0	-
7	-	-	46	11	37	-	0	-	0	-
8	-	-	37	14	14	-	.25	-	.27	-
9	-	-	37	-11	37	-	0	-	0	-
10	-	-	44	30	32	-	0	-	0	-
11	-	-	32	12	22	-	0	-	0	-
12	-	-	43	10	40	-	0	-	0	-
13	-	-	42	26	27	-	0	-	0	-
14	-	-	39	11	36	-	0	-	0	-
15	-	-	40	31	32	-	0	-	0	-
16	-	-	35	15	26	-	0	-	0	-
17	-	-	36	11	25	-	0	-	0	-
18	-	-	50	12	39	-	0	-	0	-
19	-	-	42	16	34	-	0	-	0	-
20(c)	-	-	52	28	36	-	0	-	0	-
Maximum	8	8	84	46	71	.24	.25	.27	.34	4.71
Average	4.1	3.8	-	-	-	.10	.01	.10	.02	1.62
Minimum	0	0	29	-11	14	.01	0	.02	0	0.08
Total	200	173	-	-	-	2.15	.68	4.05	1.16	-

(a) Recorders installed on Oct. 7
(b) Start of sugar campaign
(c) End of campaign
(d) Recorders removed - ice formation

• Included in following measurement

APPENDIX VI - Limnological Data

Plankton Nos. per ml.

Sta. D-1	11-1-53	Sta. D-4	11-1-53	11-3-53
Diatoms:		Diatoms:		
Cyrosigma	1	Synedra gr		9
Navicula gr	56	Navicula gr.	96	47
Synedra gr.	7	Nitzschia gr.	27	-
Nitzschia gr.	11	Cocconeis	4	2
Surirella gr.	3	Cyrosigma		1
Cymbella	3			
Rhoicosphenia	2	Green Algae:		
		Chlamydomonas	337	363
Green Algae:				
Scenedesmus bijuga	1	Protozoa:		
		Paramecuim caudatum	27	23

Ditch 150' below treatment area	Outfall	11-1-53
Diatoms:		
Cyrosigma	1	
Navicula gr.	56	
Synedra gr.	7	
Nitzschia gr.	11	
Green Algae:		
Chlamydomonas gr.	5003	
Protozoa:		
Paramecium caudatum	14	

Station F-5

Effluent from Treatment Area	11-1-53	11-3-53
Green Algae:		
Chlamydomonas	67,000	66,000
Protozoa:		
Paramecium caudatum	203	214

Green Water Areas

Chlamydomonas varied from	775,000	- 1,650,000
Paramecium caudatum	367	- 463

Gray Flow Path

Chlamydomonas	64,000
Paramecium caudatum	64

Chemical Analyses - Treatment Area and Ditch

Sta.	Date	Temp. °C	pH	CO_2 Alk. ppm	HCO_3 Alk. ppm	O_2 % Sat.	PO_4 ppm	NH_3-N ppm	NO_2-N ppm	NO_3-N ppm	
L-1	11-1-53	17	8.25	12	248	125	0.0	0.05	0.0075	1.55	
	11-2-53	17.5	8.3	14	244	122	0.0	0.05	0.005	1.57	
	11-15-53	-	-	-	-	-	0.0	0.05	0.01	1.5	
D-4	11-1-53	17	-	-	-	-	0.0	0.25	0.0275	0.55	
	11-2-53	-	-	-	-	-	0.0	0.25	0.02	0.50	
Ditch 150' below F-5	11-1-53	17	8.2	12	285	69	0.0	0.45	0.02	0.80	
Field 9-0	11-15-53	-	-	-	-	-	0.0	0.25	0.0	0.02	Gray area
Field 15-2	11-15-53	-	-	-	-	-	0.0	3.0	0.0	0.05	Green area
Field 23-2	11-15-53	-	-	-	-	-	0.0	4.0	0.0	0.05	Green area
Field 18-2	11-15-53	-	-	-	-	-	0.0	0.6	0.0	0.02	Gray area
Field 33-10	11-15-53	-	-	-	-	-	0.0	0.45	0.0	0.02	Clear water
F-5	11-15-53	Analyses 11-19-53	8.2	6.0	412	-	0.0	0.25	0.0	0.02	Effluent
Clear water area	11-1-53	-	-	-	-	18	-	-	-	-	
F-5	11-1-53	-	-	-	-	2	-	-	-	-	Effluent

Organisms developed in Treatment Area effluent after penned in Kansas City - Qualitative Only

Diatoms:
- Nitzschia amphibia
- Nitzschia capitellata
- Nitzschia linearis
- Nitzschia commutata
- Nitzschia bilobata
- Navicula cuspidata
- Navicula cuspidata var. ambigua
- Navicula gracilis
- Navicula cari
- Amphora venata

Blue-green algae:
- Oscillatoria sp.
- Merismopedia elegans

Green Algae:
- Ankistrodesmus falcatus
- Chlorella sp.
- Scenedesmus bijuga
- Chlamydomonas sp.
- Dictyosphaerium pulchellum
- Kirchneriella lunaris

Euglenophyceae:
- Euglena retronata
- Euglena rostifera
- Phacus torta

Protozoa:
- Paramecium caudatum
- Coleps octospinus
- Oxytricha fallax

Chemical Analyses of Effluent Penned on 11-19-53 - Kansas City, Missouri

Date	Temp °C	pH	CO_2 Alk ppm	HCO_3 Alk ppm	O_2 % Sat	PO_4 ppm	NH_3-N ppm	NO_2-N ppm	NO_3-N ppm
11-23-53	21	9.0	66	356	142	0.0	1.25	0.0	0.08
11-27-53	20	9.1	72	342	137	0.0	1.3	0.0	0.12
12-3-53	21	9.2	84	332	146	0.0	1.4	0.0	0.16
12-8-53	20	9.3	108	250	147	0.0	1.65	0.0	0.2
12-18-53	21	9.3	106	236	133	0.0	1.6	0.0	0.2

APPENDIX VII - Analyses Conducted by Grant Graham, Senior Chemist - 1952

LABORATORY DATA
SUMMARY OF INDIVIDUAL RESULTS

Sampling Point	Type	Date 1952	Turb. p.p.m.	Temp. °C	Dissolved Oxygen p.p.m.	% Sat.	B.O.D. 5 day p.p.m.	Coliform Bacteria M.P.N. per 100 ml.	Streptococci Bacteria M.P.N. per 100 ml.	pH	Turb. p.p.m.	Solids Total	Dissolved	Suspended	A.P.H.A. Sus. Solids	Remarks
Sta. P-1	Report analyses	10/10	-	-	-		-			-		5,552	-	1,384	4,458	
Main factory sewer	" "	10/16	8.10	-	-		-			-		5,584	-	824	4,760	
	Lovelace "	10/16	-	-	-		909			7.8		5,624	2,032	1,490	4,188	
	Report "	10/24	7.88	-	-		-			-		4,332	-	890	3,432	
	Lovelace "	10/27	8.31	-	-		315			7.7		4,618	736	950	3,668	
	Report "	10/31	8.38	-	-		-			-		6,064	-	928	5,168	
	Report "	11/7	7.15	-	-		-			-		5,644	-	1,100	4,544	
	Lovelace "	11/7	-	-	-		652			9.0		7,148	1,272	1,162	6,056	
	" "	11/13	6.11	-	-		401			7.5		5,008	1,242	1,816	3,192	
	Report "	11/13	-	-	-		-			-		3,784	-	906	2,878	
	Lovelace "	12/13	-	27	0.86		1,281			9.0		6,288	2,732	2,444	4,320	
Maximum			8.31				1,281			9.0		7,198	2,852	2,444	6,056	
Average			7.44				670			8.2		5,404	1,767	1,231	4,240	
Median			8.38				552			7.8		5,552	1,272	1,094	4,320	
Minimum			6.11				315			7.5		3,784	736	824	3,192	
Sta. P-2																
Field effluent	Report analyses	10/16	-	-	-		-			-		938	-	896	42	
	Lovelace "	10/16	-	-	-		159			7.5		1,018	270	1,002	16	
	Report "	10/24	1.05	-	-		-			-		1,060	-	1,022	38	
	Lovelace "	10/27	1.30	-	-		245			7.7		1,068	290	1,056	12	
	Report "	10/31	1.32	-	-		-			-		960	-	928	32	
	" "	11/7	1.15	-	-		-			-		965	-	899	66	
	Lovelace "	11/7	-	-	-		232			7.6		954	382	932	42	
	Lovelace "	11/13	1.46	-	-		185			7.8		986	386	966	20	
	Report "	11/13	-	-	-		-			-		922	-	902	20	
	Lovelace "	12/13	-	3	0.81		625			6.9		1,468	658	1,236	232	
Maximum			6.15				625			7.8		1,468	658	1,236	232	
Average			4.37				287			7.5		1,084	397	977	69	
Median			5.50				232			7.6		969	382	966	36	
Minimum			1.05				159			6.9		922	270	896	12	
Sta. P-3	Grab sample	10/10	-	-	-		-			-		870	-	640	230	
Factory intake	Report															
Sta. P-3	Lovelace Analyses	10/6					25			8.2		-	-	-	-	
North Platte above	" "	11/7					15			8.0		660	176	652	8	
Report	" "	11/13					4			8.5		698	192	690	8	
	" "	12/13	-	7	8.16		4			7.9		670	498	664	6	
Maximum							25			8.5		698	498	690	8	
Average							12			8.1		676	289	669	7	
Median							10			8.1		670	192	664	8	
Minimum							4			7.9		660	176	652	6	
Sta. P-3 North Platte at Report	Report Analyses	10/6										176	-	666	10	
Sta. P-4 North Platte at Bridgeport	Lovelace analyses	11/6					22			8.0		856	172	686	170	
	" "	11/13					6			8.2		986	220	722	264	
	" "	12/13		A	5.80		16			8.0		774	776	648	126	
Maximum							22			8.2		986	776	722	264	
Average							15			8.0		939	389	685	253	
Median							16			8.0		774	220	686	264	
Minimum							6			8.0		856	172	648	126	

NAVAL OUTLYING BASIN

RATE OF FLOW

1952	INPUT Cu. Ft./Sec.	DISCHARGE Cu. Ft./Sec.
Oct. 16	8.00	
17	6.12	
18	8.00	4.8
19	8.00	3.2
20	7.51	3.3
21	6.80	3.7
22	8.25	5.12
23	8.25	2.40[a]
24	7.88	1.05
25	7.51	4.91
26	7.51	4.35
27	8.25	3.50
28	8.00	3.67
29	8.25	4.15
30	8.63	5.12
31	8.38	5.70
Nov. 1	8.00	5.12
2	7.88	4.53
3	7.75	5.12
4	7.03	5.44
5	7.39	4.39
6	6.80	5.50
7	7.15	6.15
8	7.27	5.44
9	7.63	6.33
10	6.78	4.86
11	5.98	5.66
12	6.33	5.12
13	6.11	5.66
14	5.79	4.70
15	6.00	4.01
16	7.27	5.12
17	7.15	8.50[b]
AVG.	7.44	5.09
MED.	7.51	5.12

(a) Factory open for 13½ hours.

(b) Five inches snowfall caused rise in discharge.